The use of plain radiography in diagnosing osteoarthritis: a systematic review and time trend analysis

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RESEARCH ARTICLE

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The use of plain radiography in diagnosing osteoarthritis: A systematic review and time trend analysis

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Abstract

Introduction: The National Institute for Health and Care Excellence (NICE) suggest there is no role for routine radiography in the diagnosis of osteoarthritis (OA). It is not known how consistent this recommendation is across international guidelines, or the impact of UK guidance on domestic OA X-ray request rates.

Methods: A systematic search identified guideline recommendations on the role of radiography in OA diagnosis. Full texts underwent dual screening and appraisal using the AGREE II tool. A narrative synthesis was performed. Consultation data were extracted from a UK primary care database: the Consultations in Primary Care Archives (CiPCA). The annual proportion of X-ray requests per 100 OA consulters from 2000 to 2012 were calculated. Joinpoint regression analysis examined if there were changes in the trend of X-ray request rates and compared these with the publication dates of UK guidelines.

Results: Eighteen evidence-based OA guidelines were included in the review. Eleven recommended a clinical diagnosis of OA without radiographic confirmation. Seven recommended routine radiography; these guidelines were predominantly for radiologists. A mean of 17.3 X-rays per 100 patients were requested in patients consulting for OA per year between 2000 and 2012. A statistically significant reduction in X-ray request rates was seen in 2003.

Conclusion: Recommendations on the role of radiography in OA vary between medical specialty and countries. UK guidelines appear to have had a limited impact on X-ray request rates in OA.

KEYWORDS
guideline, osteoarthritis, radiography, rate, systematic review, trend, X-ray

1 | INTRODUCTION

Osteoarthritis (OA) is a leading cause of disability affecting over 500 million people globally (Hunter et al., 2020), with significant impacts on individual health, healthcare systems, and economies. Concern for affordable, effective, and equitable healthcare has directed attention to the overuse of low-value tests and treatments. Clearly ineffective tests may be relatively rare. Many more are likely to belong in a 'grey zone' offering limited benefit to most patients, or where evidence of their benefits and harms is lacking (Brownlee

et al., 2017). Routine use of opioid analgesia (Bannuru et al., 2019; Kolasinski et al., 2020), glucosamine sulphate, arthroscopic lavage/debridement (NICE, 2014b; RACGP, 2018), and magnetic resonance imaging (Department of Veterans Affairs and the Department of Defense, 2020) have been extensively investigated and attracted multiple 'do not do' recommendations. However, use of plain film radiography in the diagnosis of OA, the focus of the current study, also lies within the 'grey zone', where its value continues to be contested (Wang et al., 2018).

Capable of visualising predominately bony morphological changes, sensitive to the protocols and views used, and with sometimes marked discordance between appearances on X-ray and symptom severity, the limitations of plain film radiography in OA diagnosis are well-documented (Glyn-Jones et al., 2015). There is some evidence against the additional value of X-rays in clinical decision making and patient outcomes (Bedson & Croft, 2008; Skou et al., 2014; Wang et al., 2018). One study observed that, independent of pain severity, patients found to have severe radiographic hip OA were more likely to be referred earlier for surgery (Dolin et al., 2003), bypassing potentially effective non-surgical treatments.

A recent review ranked knee radiographs as one of the most overused tests in primary care (O'Sullivan et al., 2018), although the estimate came from a single study conducted in 2001 (Eccles et al., 2001). Nevertheless, plain radiographs are relatively inexpensive, widely accessible, and appear to still be commonly used in many countries in the course of diagnosing and managing OA (Glyn-Jones et al., 2015), although recent UK data on levels of use are lacking (Brand et al., 2014; Jordan et al., 2017; Morgan et al., 1997; Smink et al., 2014; Yu et al., 2017).

Previous reviews of OA guidelines have either concentrated on treatment (Nelson et al., 2014; Pencharz et al., 2001; Zhang et al., 2007), were specific to a single joint (Lee et al., 2021), pre-date the publication of several prominent national OA guidelines (Misso et al., 2008), or only include guidelines published in journals (Lee et al., 2021).

Our study had three aims:

(i) To synthesise current recommendations from clinical practice guidelines on the use of plain film radiography in the diagnosis of OA.
(ii) To describe trends in the use of plain radiography in routine general practice.
(iii) To explore the relationship between the timing of relevant guideline publication and the above trends.

2 | METHODS

2.1 | Systematic review of recommendations in international guidelines

The review was reported with reference to PRISMA guidance (Page et al., 2021), and prospectively registered on PROSPERO (CRD42019155893).

2.1.1 | Selection criteria

A single reviewer, CHB, initially screened all titles. Subsequently, each abstract and full text underwent independent double screening (CHB and KT) using Rayyan (Ouzzani et al., 2016). Inclusion criteria were: (1) evidence-based diagnostic guidelines for OA, (2) guidelines developed by guideline development groups, (3) guidelines based on a systematic review of evidence, (4) guidelines reported in English. Exclusion criteria were: (1) guidelines addressing OA management only, (2) guidelines addressing only spinal or temporomandibular OA, (3) guidelines superseded by updated versions.

2.1.2 | Search terms

OA and guidelines were identified using the terms 'osteoarthritis, OA, arthrosis and degenerative arthritis' and 'guideline development group, guideline, guidance, diagnostic criteria and recommendation' respectively (Appendix 1). Medical Subject Headings (MeSH) terms relevant to OA and guidelines were also included. The strategy was implemented on a comprehensive range of databases: Medline (1946–October 2019), CINAHL (1963–October 2019), BNI (1992–October 2019), EMBASE (1974–October 2019), HMIC (1979–October 2019), AMED (1995–October 2019); guideline specific databases: TRIP (1990–October 2019), Guideline Central (2000–October 2019), CPG Infobase (2017–October 2019), Guideline International Network (1998–October 2019), Epistemonikos (1994–October 2019); and websites of prominent organisations with an interest in OA: European League Against Rheumatism (EULAR), National Institute for Health and Care Excellence (NICE), Scottish Intercollegiate Guidelines Network, British Society for Rheumatology, Royal College of General Practitioners, Royal College of Radiologists (RCR), American College of Radiology, American College of Rheumatology, and the Osteoarthritis Research Society International.

The search was completed by 30 October 2019. A list of known guidelines was checked with the pilot search to ensure face validity.

2.1.3 | Data extraction and quality assessment

A single reviewer, CHB, using a standard proforma, extracted guideline characteristics and recommendations regarding the role of radiography in diagnosing OA. Characteristics included institution name, guideline publication date, region organisation represents, target audience and joint site; and recommendations for diagnosing OA. If data could not be found, a second reviewer (KT) independently re-reviewed the guideline. Unpublished additional information was not sought. Recommendations were grouped by joint site, and a narrative synthesis was performed.

Two reviewers, CHB and KT, independently appraised each guideline against the AGREE II tool that assesses guideline quality across six domains (Brouwers et al., 2010).

2.2 | Analysis of trends in plain radiography in relation to guideline publication

2.2.1 | Data source

Consultation data and X-ray referral data were obtained from the Consultations in Primary Care Archives (CiPCA) database. The CiPCA database contains prospectively collected consultation data from nine general practices in the North Staffordshire area from January 2000 to December 2015 (Porcheret et al., 2004). From 2013 onwards there was automated electronic transfer of coded results to the EMIS clinical system. X-ray coding became less user dependent. Analysis was restricted to 2000–2012 to prevent the distortion of trend rates because of changing coding procedures. Two practices who had dramatic rises in X-ray request rates from 2013 onwards were removed as this change indicated unreliable coding practices prior to 2013.

2.2.2 | Ethical approval

The CiPCA database gained ethical approval as a research database in April 2017 from Northwest Haydock Research Ethics Committee (Ref: 17/NW/0232).

2.2.3 | Population

The OA population was defined as any primary care patient ≥45 years of age whose consultation resulted in one or more clinical OA Read codes. This study defined 'clinical OA' as OA diagnostic Read codes or joint pain Read codes in a patient ≥45 years of age. The Read codes were taken from an established Read code list produced by six experienced clinicians and used in previous studies (Jordan et al., 2016; Sakellariou et al., 2017; Yu et al., 2017). If a patient had multiple OA consultations in a month, the first OA consultation was chosen.

2.2.4 | Estimating the trend in X-ray requests

An X-ray associated with an OA consultation was defined as a primary care patient ≥45 years of age, with a recorded X-ray Read code within 30 days either side of a clinical OA Read code. The joints included the foot, ankle, knee, hip, wrist, and hand. Codes were obtained from the 'Operations, Procedures, and Investigations' domain of the 'Clinical Terminology Browser Version 3'. If a patient had multiple X-rays in a single month, only the first X-ray was chosen. When estimating the proportion of patients who received an X-ray request for OA in each period, a patient could only be counted once. The proportion of patients who consulted for OA in which an X-ray was requested was calculated for each quarter, and each year, from January 2000 to December 2012. To assess the presence of a statistically significant change in the trend in X-ray request rates, the Joinpoint Regression Program, Version 4.7.0, was used, provided by the National Cancer Institute. Joinpoint analysis assumes all trends can be split into straight line segments, separated by a joinpoint. The software then creates a series of models, each with one extra joinpoint. A likelihood ratio test statistic is calculated to assess if a model with one extra joinpoint is a better fit to the observed data than the previous model. A $p = 0.05$ was chosen.

2.2.5 | Estimating the impact of guidelines on X-ray request rates

The location of any joinpoints were compared with the publication dates of UK national guidelines during the study period of 2000–2012. If no joinpoints were found, there were no significant changes in the trend in X-ray request rates. If a joinpoint aligns within a year of guideline publication, this may indicate that guidelines have had some impact on X-ray request rates. If a joinpoint does not align with a guideline publication date, this could indicate another factor not accounted for, is impacting X-ray request rates.

3 | RESULTS

3.1 | Systematic review

Following removal of duplicates, 4540 potentially relevant titles were identified, of which 122 full-text articles remained after title and abstract screening (Figure 1). Eighteen eligible guidelines, published between 1998 and 2019, by organisations in North America (9), Europe (7), Asia (1), and Australasia (1), were included in the narrative synthesis (Table 1).

The guidelines considered OA at any joint ($n = 8$), at the knee ($n = 3$), hip ($n = 2$), hand ($n = 2$), wrist ($n = 1$), foot ($n = 1$), and ankle ($n = 1$) (Table 1). The target audience included general practitioners/primary care physicians ($n = 11$), radiologists ($n = 7$), rheumatologists ($n = 4$) and orthopaedic surgeons ($n = 3$). Of the 18 guidelines included in this systematic review, 13 were first editions, four were updates, and one was an adaptation.

Critical appraisal of the guidelines using AGREE II found they scored highest on the scope and purpose domain (87%) (Figure 2), followed by the clarity of presentation domain (83%). The rigour of development (69%), editorial independence (69%), and stakeholder involvement (66%) domains scored similarly. The applicability domain scored lowest (32%). Agreement between the two independent assessors was 86%.

Eleven OA guidelines suggested an OA diagnosis should be made clinically, seven of these covered multiple joints (Ariani et al., 2019; Bussières et al., 2008; Department of Veterans Affairs and the Department of Defense, 2014; Melorose et al., 2013; NICE, 2014b; RACGP, 2018; Sakellariou et al., 2017), with two focussed on knee OA (Royal College of Radiologists, 2017; Zhang et al., 2010), one on

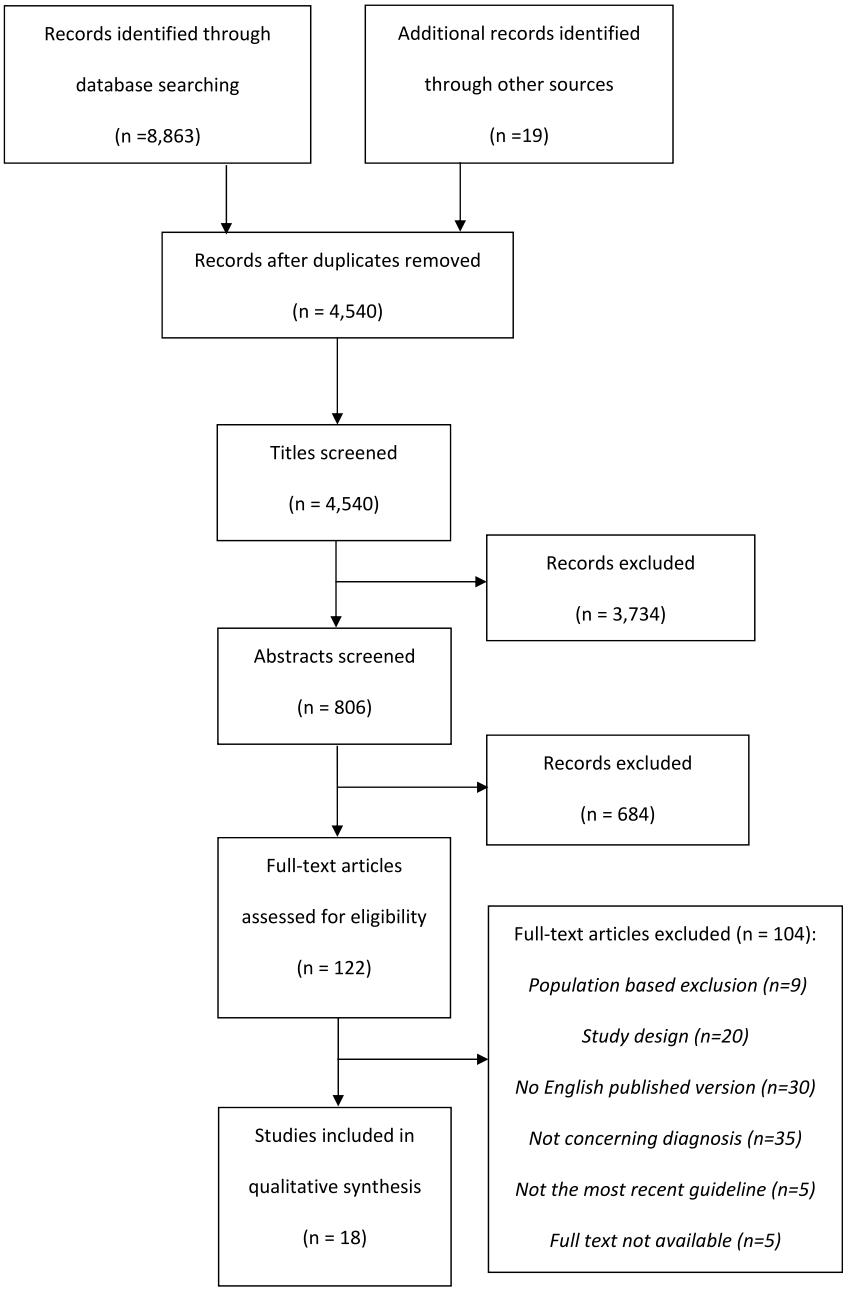

FIGURE 1 A PRISMA flow diagram highlighting the search screening process

hip OA (Cibulka et al., 2017) and another on hand OA (Zhang et al., 2009) (Table 1). Seven guidelines recommended a radiographic diagnosis of OA at one or more joint sites; each guidelines' advisory group were composed predominantly of radiologists (Chang et al., 2018; Fox et al., 2018; Jacobson et al., 2017; Mintz et al., 2017; Royal College of Radiologists, 2017; Rubin et al., 2018; Wise et al., 1998). One guideline's recommendations varied by joint site: radiographic confirmation was recommended at the hip, but not the knee (Royal College of Radiologists, 2017).

All guidelines identified that the first line imaging modality should be plain radiography. Although 11 guidelines indicated a preference towards a clinical diagnosis of OA, only three guidelines explicitly discouraged routine radiography (NICE, 2014a; RACGP, 2018; Sakellariou et al., 2017) (Table 1). Seven guidelines advised that radiographic features do not correlate well with symptoms (Bussières et al., 2008; Cibulka et al., 2017; Department of Veterans Affairs and the Department of Defense, 2014; NICE, 2014a; RACGP, 2018; Sakellariou et al., 2017; Zhang et al., 2010). Four guidelines state that radiographic features do not predict non-surgical treatment response (Ariani et al., 2019; Bussières et al., 2008; RACGP, 2018; Sakellariou et al., 2017).

Indications for radiography included: to confirm an uncertain OA diagnosis (Ariani et al., 2019; Bussières et al., 2008; Department of Veterans Affairs and the Department of Defense, 2014; Melorose et al., 2013; NICE, 2014a; RACGP, 2018; Sakellariou et al., 2017; Zhang et al., 2009, 2010) when there is a rapid progression in

TABLE 1 Characteristics of the identified osteoarthritis diagnostic guidelines

Organisation (abbreviation)	Region	Predominant specialism	Joint site (reference)	Support routine radiography	Diagnostic criteria
European League Against Rheumatism & European Federation of National Associations of Orthopaedics and Traumatology (EULAR/EFORT)	Europe	Orthopaedic surgeons	Knee (Landewé et al., 2010)	Yes	Not specified
American College of Radiology (ACR)	United States	Radiologists	Hip (Mintz et al., 2017)	Yes	Not specified
			Ankle (Chang et al., 2018)	Yes	Not specified
			Foot (Wise et al., 1998)	Yes	Not specified
			Knee (Fox et al., 2018)	Yes	Not specified
			All joints (Jacobson et al., 2017)	Yes	Not specified
			Wrist (Rubin et al., 2018)	Yes	Not specified
Royal College of Radiology (RCR)	United Kingdom	Radiologist	Hip (Royal College of Radiologists, 2017)	Yes	Radiographic
			Knee (Royal College of Radiologists, 2017)	No	Clinical
US Department of Veteran Affairs & Department of Defense (DOD)	United States	Orthopaedic surgery	All joints (Department of Veterans Affairs and the Department of Defense, 2014)	No	Not specified
European League Against Rheumatism (EULAR)	Europe	Rheumatologists	Knee (Zhang et al., 2010)	No	Clinical
			Hand (Zhang et al., 2009)	No	Clinical
			All joints (Sakellariou et al., 2017)	No	Not specified
Malaysia Health Technology Assessment Section (MaHTAS)	Malaysia	Rheumatologists	All joint (Melorose et al., 2013)	No	Clinical or Radiographic or Laboratory
Italian Society for Rheumatology (ISR)	Italy	Rheumatologist	All joints (Ariani et al., 2019)	No	Not specified
Royal Australian College of General Practitioners (RACGP)	Australia	General practice	All joints (RACGP, 2018)	No	Clinical
National Institute for Health and Care Excellence (NICE)	United Kingdom	General practice	All joints (NICE, 2014b)	No	Clinical
American Physical Therapy Association (APTA)	United States	Physical therapists	Hip (Cibulka et al., 2017)	No	Clinical
Guideline development group of the Diagnostic imaging guideline for musculoskeletal complaints in adults (DIG)	Canada	Chiropractors	All joints (Bussières et al., 2008)	No	Clinical

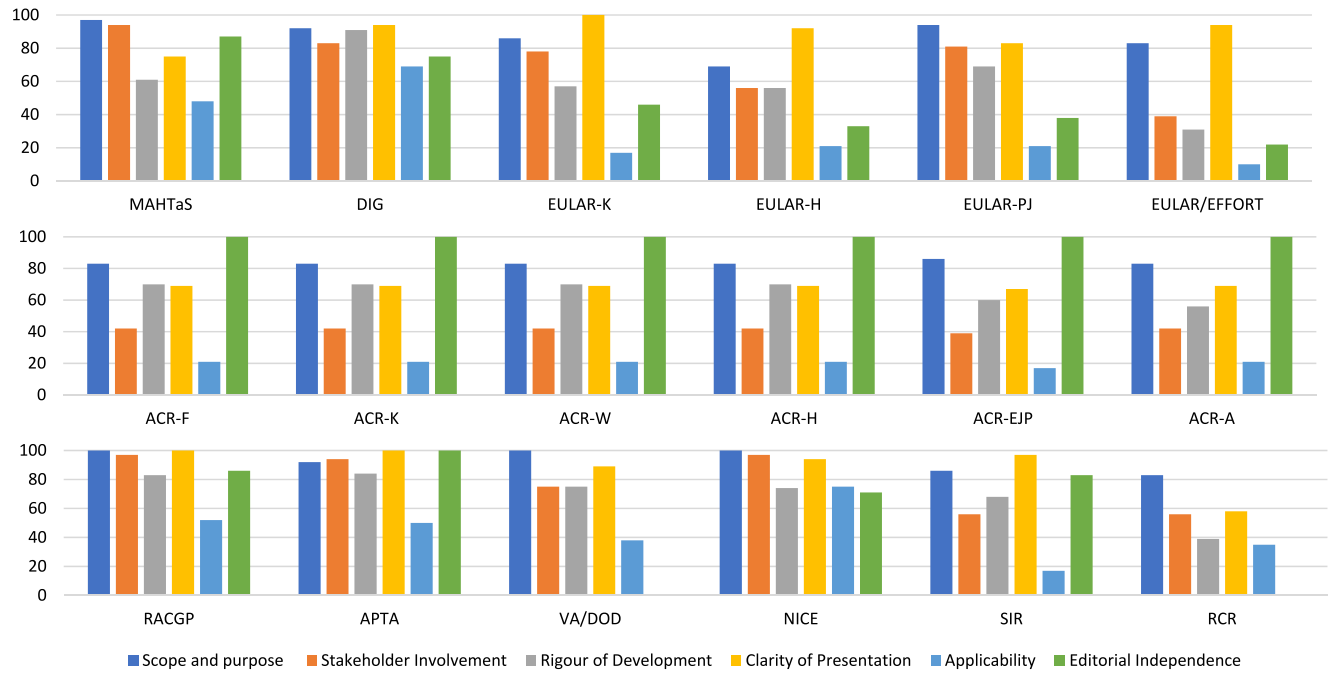

FIGURE 2 A bar chart outlining the AGREE II domain scores for each osteoarthritis diagnostic guidelines. ACR-A, appropriateness criteria: chronic ankle pain; ACR-EJP, appropriateness criteria chronic extremity joint pain: suspected inflammatory arthritis; ACR-F, appropriateness criteria: chronic foot pain; ACR-H, appropriateness criteria: chronic hip pain; ACR-K, appropriateness criteria: chronic knee pain; ACR-W, appropriateness criteria: chronic wrist pain; APTA, Hip Pain and Mobility Deficits-Hip OA: Revision 2017; DIG, diagnostic imaging guideline for musculoskeletal complaints in adults-an evidence-based approach-part 2: upper extremity disorder; EULAR/EFFORT, EULAR/EFORT recommendations for the diagnosis and initial management of patients with acute or recent onset swelling; EULAR-H, evidence-based recommendations for the diagnosis of hand OA: report of a task force of ESCISIT; EULAR-K, evidence based recommendations for the diagnosis of knee OA; EULAR-PJ, EULAR recommendations for the use of imaging in the clinical management of peripheral joint OA; MaHTAS, clinical practice guideline: management of OA; NICE, Osteoarthritis: Care and Management; RACGP, Guideline for the management of knee and hip osteoarthritis; RCR, iRefer: Making the best use of Clinical radiology; SIR, The Italian Society for Rheumatology clinical practice guidelines for the diagnosis and management of knee, hip and hand osteoarthritis; VA/DOD, The Non-Surgical Management of Hip & Knee OA

symptoms (RACGP, 2018; Sakellariou et al., 2017), to stage disease severity (Ariani et al., 2019; Melorose et al., 2013), for all non-traumatic hip pain (Royal College of Radiologists, 2017), for arthropathy of the hands and feet (Royal College of Radiologists, 2017), for shoulder pain lasting >4 weeks (Bussières et al., 2008) and to differentiate types of hand arthritis (Melorose et al., 2013.)

3.2 | Trends in plain radiography requests in general practice

Of the seven GP practices included in this study from 2000 to 2012, the sum of all patients who had at least one OA consultation in a year was 38,415. Considering consultations by the same patient on multiple years, over the 12-year study period, 18,114 individual patients had at least one OA consultation. 10,621 (58.6%) were females and 14,981 (82.2%) were white. The population was disproportionately deprived (Table 2).

The rate of X-rays requests remained relatively stable over the study period, averaging 17.3 X-rays per 100 patients consulting for OA per year (range: 14.3 [2000], to 19.8 [2003]) (Figure 3). The largest percentage increase was 15.5% and occurred between 2002 and 2003. 2003 had the highest rate of X-ray requests, with 19.8 X-rays per 100 patients consulting for OA. The largest annual percentage decrease was 12.8%, which occurred from 2009 to 2010.

3.3 | Relationship between guideline publication and trend in X-ray request rate

Two segments were identified through the joinpoint analysis (Figure 4). The first segment was from quarter 1 in 2000 to quarter 2 in 2003. The percentage change per quarter for this segment was 2.6% (95% CI: 1.0, 4.3). The second segment of the analysis showed a decreasing trend from quarter 2 2003 to quarter 4 2012. The percentage change per quarter for this segment was −0.5% (95% CI: −0.8, −0.2).

One joinpoint was identified at quarter 2 2003 (95% CI: quarter 2 2002, quarter 2 2004) between the two segments. During the study period of 2000–2012, four UK OA diagnostic guidelines were identified by the systematic review (Table 3). This joinpoint coincides within 6 months of the publication of the Royal College of Radiologists (2003) guideline.

TABLE 2 Baseline characteristics of the OA population

Baseline OA population characteristics	Frequency (%)
Female gender	10,621 (58.6)
Age (years)	
45–54	4968 (27.4)
55–64	5008 (27.6)
65–74	4099 (22.6)
75+	4039 (22.3)
Ethnicity	
White or white British	14,891 (82.2)
Not coded	3029 (16.7)
Asian or Asian British	126 (0.7)
Mixed ethnicity	28 (0.2)
Black or black British	27 (0.1)
Other ethnic group	13 (0.1)
GP practice	
1	3360 (18.5)
2	2030 (11.2)
4	2877 (15.9)
5	2878 (15.9)
6	2366 (13.1)
7	2809 (15.5)
9	1794 (9.9)
Indices of multiple deprivation quintile	
1 (most deprived)	2034 (11.2)
2	6798 (37.5)
3	6554 (36.2)
4	2727 (15.1)
5 (least deprived)	1 (0.0)

Abbreviation: OA, osteoarthritis.

4 | DISCUSSION

This study aimed to synthesise guideline recommendations on the role of routine radiography in OA, assess trends in the rates of X-ray requests and describe the relationship between UK guideline publication dates and the trend in X-ray request rates. A systematic search and narrative synthesis of current OA guidelines found that 18 international guidelines considered the role of radiography in the diagnosis of OA between 1998 and 2019. Eleven guidelines recommended a clinical diagnosis of OA; however, seven guidelines, written predominantly by radiologists recommended radiographic confirmation of OA at one or more joint sites. Trends in the rate of X-rays requested in routine general practice remained relatively stable between 2000 and 2012, averaging 17.3 X-rays per 100 patients consulting for OA per year. Joinpoint analysis indicated one statistically significant change in the trend in X-ray request rates which coincided with the publication of the UK Royal College of Radiologists (2003) guideline.

Most guidelines did not recommend routine radiography when diagnosing OA. Radiographic features do not strictly correlate with clinical signs and symptoms and as such have not been shown to improve diagnostic certainty in patients with typical clinical features of OA (Skou et al., 2014; Wang et al., 2018). Over-reliance on radiography may cause harm through altering conclusions. A UK based study analysing orthopaedic surgeons' management decisions for knee OA found the addition of a single radiographic view altered management in 42% of cases and increased rates of surgery (Ritchie et al., 2004). Similarly, at the hip, the addition of radiographs was associated with higher rates of hip replacements, independent of pain scores (Dolin et al., 2003). As X-rays do not correlate well with patient symptoms, but result in higher rates of surgical interventions, effective non-surgical management strategies may be overlooked, resulting in poor patient outcomes and an inefficient use of resources.

One factor determining the use of X-rays is the formation of habits (Egerton et al., 2018). Practitioners are more likely to alter habits with a greater understanding of the benefits of the proposed change (Hunter et al., 2018; Lugtenberg et al., 2009). The systematic review found seven guidelines discussed the discordance between radiographic features and clinical symptoms and four guidelines suggested X-ray features do not predict non-surgical treatment response (Ariani et al., 2019; Bussières et al., 2008; Cibulka et al., 2017; Melorose et al., 2013; NICE, 2014a; RACGP, 2018; Sakellariou et al., 2017; Zhang et al., 2010). However, only the RACGP (2018) and NICE (2014b) guidelines explained that radiography can potentially result in harm. It is unclear how well UK practitioners understand the relative benefits and harms of diagnostic radiographs for OA, but there has been little change in X-ray referral rates between 2000 and 2012. Practitioners may use radiographs as a tool to facilitate consultations rather than as a diagnostic test; a belief that X-rays provide patient reassurance, and pessimism about management options are all factors that cause practitioners to deviate from X-ray recommendations despite awareness (Morgan et al., 1997; Spitaels et al., 2017).

The proximity of a joinpoint to a guideline publication date has previously been used to evaluate the effectiveness of guidelines on changing clinical practice (Bedson et al., 2013; Huang et al., 2010). The Royal College of Radiologists (2003) guideline was temporally associated with a statistically significant change in X-ray request rates. However, this association is unlikely to be causal. First, the Royal College of Radiologists (2003) guideline was more supportive of radiography than its predecessor, the Royal College of Radiologists (1995) guideline, and therefore would not explain the slight reduction seen in the use of radiography. Secondly, a UK study analysed the trend in requested primary care investigation from 2000 to 2015 (O'Sullivan et al., 2018). From 2000 to 2004 the rate of investigations requested by GPs increased by 21% per year, however from 2004 to 2008 the rate of investigations ordered increased at a

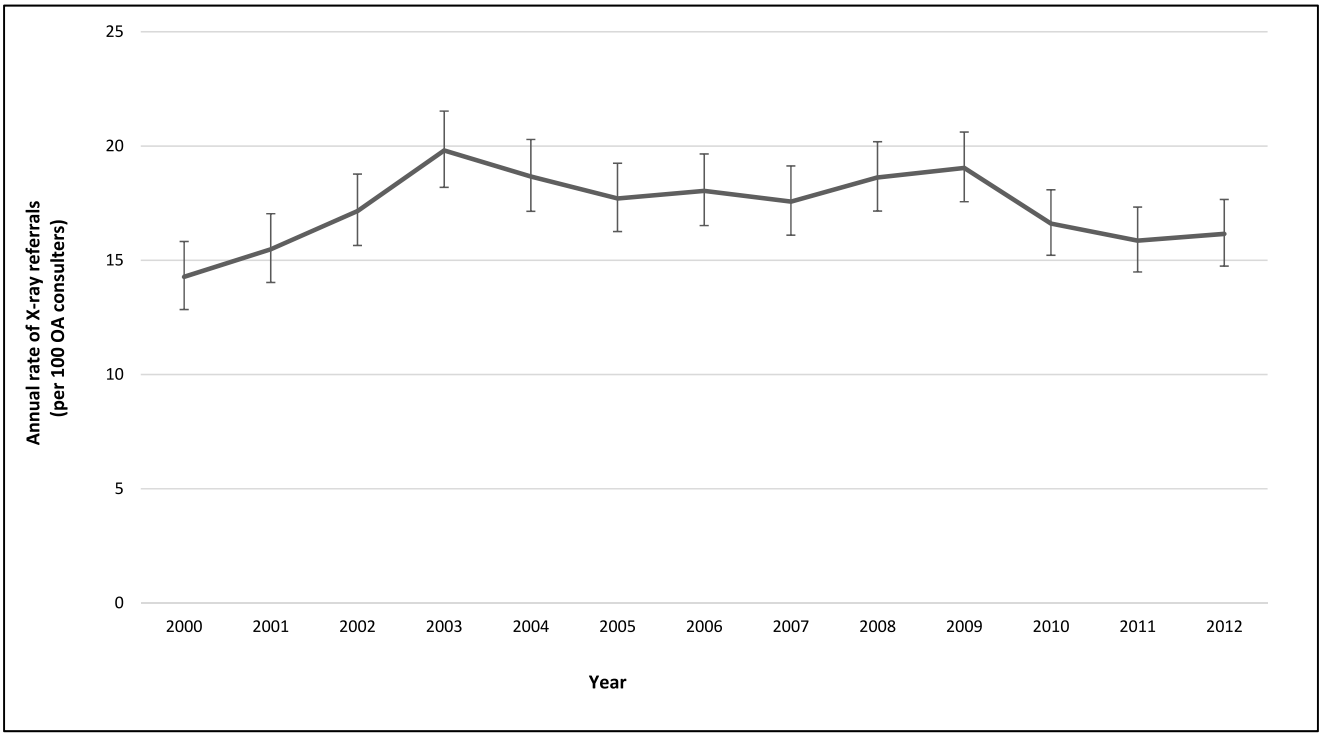

FIGURE 3 Trend in X-ray rates from 2000 to 2012

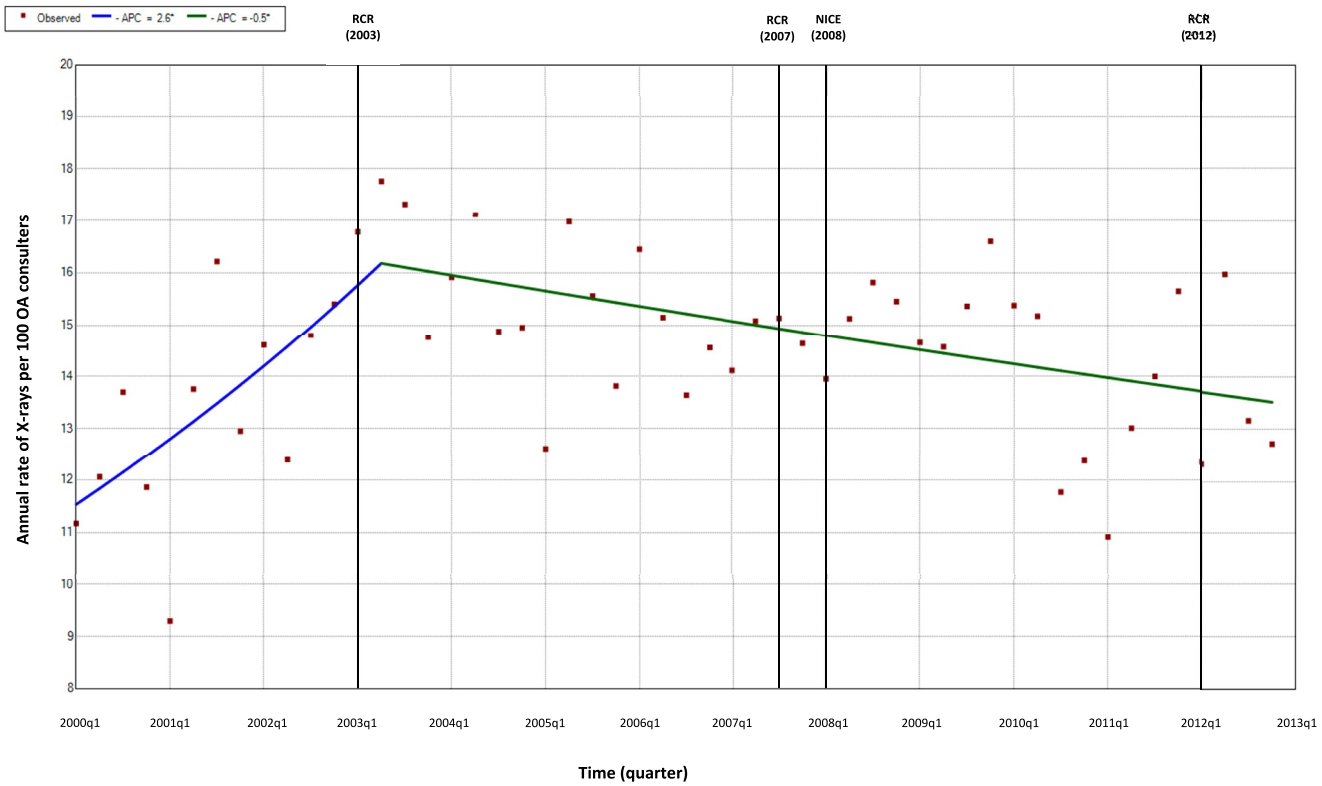

FIGURE 4 National osteoarthritis guideline publication dates and the trend in X-ray request rates from 2000 to 2012

slower rate of 7.2% per year; imaging requests were particularly volatile. This could indicate that the 2003 joinpoint reflects a broader change in the use of imaging in primary care. It is unlikely that the Royal College of Radiologists (2003) guideline or the NICE (2008) guideline were particularly effective in changing practitioners' behaviour.

TABLE 3 The UK guideline recommendations and publication dates for OA from 2000 to 2015

Publication date	Publisher	Guideline	Guideline recommendation
30 June 2003	RCR	Making the best use of a department of clinical radiology: guidelines for doctors	• X-rays of the pelvis are indicated in specific circumstances of hip pain[a] • X-rays of the knee are indicated in specific circumstances of knee pain[a] • X-rays of the hands and feet are indicated • X-rays may be necessary for specialist assessment • X-rays are necessary for knee replacement surgery
1 September 2007	RCR	Making the best use of clinical radiology services	• X-rays of the pelvis are indicated for hip pain[a] • X-rays of the knee are indicated in specific circumstances of knee pain • X-rays of the hands and feet are indicated • X-rays may be necessary for specialist assessment • X-rays are necessary for knee replacement surgery
27 February 2008	NICE	Osteoarthritis: the care and management of osteoarthritis in adults	• In patients with typical symptoms of OA, further investigations are not necessary
23 February 2012	RCR	iRefer: making the best use of clinical radiology	• X-rays of the pelvis are indicated for hip pain • X-rays of the knee are indicated in specific circumstances of knee pain • X-rays of the hands and feet are indicated • X-rays may be necessary for specialist assessment • X-rays are necessary for knee replacement surgery

Note: Radiographic guideline recommendations and their year of publication adapted from NICE Osteoarthritis: care and management 2008, 2014; Royal College of Radiologists: Making the best use of clinical radiology 2003, 2007, 2012.

Abbreviations: NICE, National Institute for Health and Clinical Excellence; OA, osteoarthritis; RCR, Royal college of Radiology.

[a]Change in guideline recommendation from previous edition.

Reminder systems, in the form of audits with feedback, can be efficacious in changing behaviour. In a UK primary care randomised controlled trial, all practices received the Royal College of Radiology guidelines, but intervention practices also received a reminder attached to all X-rays re-iterating the limited role of radiography in the routine diagnosis of OA. After 1 year, the rate of X-ray requests fell by 20%, and this reduction was maintained over a further 12 months (Eccles et al., 2001; Ramsay et al., 2003). A Cochrane review assessing effectiveness of audit and feedback on changing practitioners' behaviours found a 4.3% absolute increase in desired practice due to various audit and feedback interventions. The variation in effectiveness of audit and feedback mechanisms are related to the regularity of feedback, the position of those providing feedback and if the feedback is written or verbal (Ivers et al., 2012).

Previous systematic reviews of OA guidelines focussed on management or focussed on specific joint (Kinds et al., 2011; Lee et al., 2021; Pencharz et al., 2001; Zhang et al., 2007). A recent review on the role of imaging in knee OA searched PubMed for published clinical guidelines, which only identified four guidelines (Lee et al., 2021). The current study included an extensive search of six bibliographic databases, four health improvement and guideline databases as well as a hand search of nine professional organisations' websites for guidelines across all OA sites except the spine and temporomandibular joint. Furthermore, each abstract and full text underwent double screening, which is associated with a substantial improvement in detecting relevant articles (Waffenschmidt et al., 2019). This systematic review captured a wide range of evidence-based guidelines from various stakeholders on the role of plain radiography in the diagnosis of OA in primary care. Each guideline was appraised by two researchers, reducing the impact of a single researcher's bias on assessing guideline quality. A further strength of this study is the time-trend analysis, which used both joint pain and diagnostic OA Read code groups to improve the sensitivity of identifying early OA patients, improving the generalisability of this study; as initial OA presentations to primary care are often coded with joint pain, rather than diagnostic OA read codes (Jordan et al., 2016).

There are several limitations that should be noted. A single reviewer undertook the data extraction for the systematic review which can lead to errors and missed data (Buscemi et al., 2006). Furthermore, the search was completed in 2019, since which several guidelines included in this study have been updated (American College of Radiology, 2022; Department of Veterans Affairs and the Department of Defense, 2020; NICE, 2022). However, these updates did not include changes to the recommendations made about the role of routine radiography in the diagnosis of OA, and thus have not changed the conclusions of this study. Originally the aim of the time-trend analysis was to assess the impact of guidelines on X-ray request rates from 2000 to 2019. However, due to a major shift in practice coding after 2012, because of a new computer-linked reporting system, analysis was restricted from 2000 to 2012. Electronic health records are prone to information bias introduced through inappropriate coding. Although steps were taken to limit the impact of inappropriate coding, undetected inappropriate coding may bias the results. However, as the main aim of this study was to assess trend in X-ray requests rates, if this coding is consistent over the study period, this should not mask the impact guidance has on changing X-ray request rates. Current studies assessing the use of

X-rays in OA are limited by the inability to assess the appropriateness of an X-ray using routinely recorded electronic health record data (Brand et al., 2014; Morgan et al., 1997; Yu et al., 2017). Based on the existing literature the assumption has been made that a high degree of inappropriate X-rays are requested (Brand et al., 2014; Jordan et al., 2017; Morgan et al., 1997; Yu et al., 2017). However, in the unlikely event that all X-rays identified are appropriate, the lack of observed responsiveness to the publication of guidelines would indicate that guidelines are successful in guiding practitioner behaviour. Future research to assess the appropriate proportion of X-ray requests in a representative population could place any future research evaluating X-ray request rates into a clinical context. Furthermore, this figure could be used as a target in audit and feedback cycles by practices to help drive down excessive requesting of X-rays for OA. Finally, the relevance of this study to current clinical practice can be questioned. The emergence of the SARS-CoV-2 (COVID-19) has accelerated a shift from face-to-face consultations to remote consultations, resulting in fewer opportunities to perform examinations to detect clinical signs (Greenhalgh et al., 2020). In this circumstance, routine radiography may improve diagnostic certainty. A similar study using joinpoint analysis could determine if Coronavirus-19 has impacted the way X-rays are requested for OA. If there is a new emerging role for X-rays, guidelines may need updating.

5 | CONCLUSION

Most guidelines agree that the role of radiography in the diagnosis of OA is limited. However, this recommendation was presented in long, inaccessible guidelines with ambiguous wording and a lack of supporting scientific rationale; this may indicate why guidelines appear to have had a limited impact on reducing X-ray request rates for OA between 2000 and 2012. If UK clinicians and commissioners believe that radiography continues to have a limited role in the diagnosis and management of OA despite remote consultations, new ways of increasing adherence to guidelines need to be implemented. If X-rays are not effective in diagnosing OA, or predicting non-surgical treatment response, its use should be limited to uncertain cases where practitioners must rule out fracture, calcium pyrophosphate deposition, or avascular necrosis and radiology departments could automatically reject plain radiograph requests to diagnose routine OA or to assess OA severity. If core treatment interventions (exercise, healthy weight maintenance, and patient education; relatively safe analgesics are ok to supplement these) have failed, patients should be referred to musculoskeletal specialists for further management. Potential patient benefits from this may include greater access to core OA treatments for all, as well as access to specialist services depending upon clinical appropriateness rather than radiological severity. The healthcare system may be made more efficient by more rational use of radiological investigations and surgical interventions for the most common musculoskeletal condition.

AUTHOR CONTRIBUTIONS

Michelle Marshall, John J. Edwards and George Peat conceived and designed the study. Connor Henry-Blake performed the searches. Connor Henry-Blake, Kane Treadwell, Simran Parmar and Jordan Higgs screened the articles and undertook the data extraction. Connor Henry-Blake performed the time trend analyses and all authors interpreted data. Connor Henry-Blake drafted the manuscript, and all authors revised the article critically for important intellectual content and approved the final version of the manuscript.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

CiPCA data cannot be shared due to the conditions of its ethics approval.

ETHICS STATEMENT

The CiPCA database gained ethical approval as a research database in April 2017 from Northwest Haydock Research Ethics Committee (Ref: 17/NW/0232).

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APPENDIX 1 Search strategies used for each database

Medline (OVID) search strategy for the systematic review of national and international guidelines for the diagnosis of OA	
1	exp Osteoarthritis/
4	osteoarth*.ti,ab,kf.
5	OA.ti,ab,kf.
6	arthrosis.ti,ab,kf.
7	(degenerative adj3 arthr*).ti,ab,kf.
8	or/1-6
9	practice guideline/
10	Practice Guidelines as Topic/
11	Consensus Development Conference/
12	"guideline development group".ab.
13	guideline*.ti,kw.
14	guidance.ti,kw.
15	(diagnos* adj criter*).ab.
16	recommendation*.ti,kw.
17	(practice adj (guideline* or guidance or recommendation*)).ab.
18	(clinical adj (guideline* or guidance or recommendation*)).ab.
19	(diagnos* adj5 (gui deline* or guidance or recommendation*)).ab.
20	9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19
21	8 and 20

(Continues)

AMED (EBSCO) search strategy for the systematic review of national and international guidelines for the diagnosis of OA	
1	TI osteoarth*
2	AB osteoarth*
3	TI osteoarth*
4	AB osteoarth*
5	KW osteoarth*
6	KW OA
7	TI OA
8	AB OA
9	TI arthrosis
10	AB arthrosis
11	SU arthrosis
12	TI (degenerative adj3 arthr*)
13	TI degenerative adj3 arthr*
14	TI degenerative N3 arthr*
15	AB degenerative N3 arthr*
16	SU degenerative N3 arthr*
17	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16
18	AB "guideline development group"
19	TI guideline*
20	AB guideline*
21	TI guidance
22	SU guidance
23	AB diagnos* N1 criter*
24	TI recommendation*
25	SU recommendation*
26	KW recommendation*
27	AB (practice N1 (guideline* or guidance or recommendation*)).
28	AB (clinical N1 (guideline* or guidance or recommendation*)).
29	AB (diagnos* N1 (guideline* or guidance or recommendation*)).
30	S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28 OR S29
31	S17 AND S30
CINAHL (EBSCO) search strategy for the systematic review of national and international guidelines for the diagnosis of OA	
1	(MH "Osteoarthritis+")
2	TI osteoarth*
3	AB osteoarth*
4	SU osteoarth*
5	TI OA
6	AB OA
7	SU OA
8	TI arthrosis
9	AB arthrosis

APPENDIX 1 (Continued)

10	SU arthrosis
11	TI (degenerative N3 arthr*)
12	AB (degenerative N3 arthr*)
13	SU (degenerative N3 arthr*)
14	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13
15	(MH "Practice Guidelines")
16	(MH "Consensus")
17	TI guideline*
18	SU guideline*
19	TI guidance
20	SU guidance
21	AB diagnos* N1 criter*
22	TI Recommendation*
23	SU Recommendation*
24	AB (practice N1 (guideline* or guidance or recommendation*)).
25	AB (clinical N1 (guideline* or guidance or recommendation*))
26	AB (diagnos* N1 (guideline* or guidance or recommendation*))
27	(S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26)
28	S14 AND S27
Medline (OVID) search strategy for the systematic review of national and international guidelines for the diagnosis of OA	
1	exp Osteoarthritis/
2	osteoarth*.ti,ab,kf.
3	OA.ti,ab,kf.
4	arthrosis.ti,ab,kf.
5	(degenerative adj3 arthr*).ti,ab,kf.
6	1 or 2 or 3 or 4 or 5
7	practice guideline/
8	Practice Guidelines as Topic/
9	Consensus Development Conference/
10	"guideline development group".ab.
11	guideline*.ti,kw.
12	guidance.ti,kw.
13	(diagnos* adj criter*).ab.
14	recommendation*.ti,kw.
15	(practice adj (guideline* or guidance or recommendation*)).ab.
16	(clinical adj (guideline* or guidance or recommendation*)).ab.
17	(diagnos* adj5 (guideline* or guidance or recommendation*)).ab.
18	7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17
19	6 and 18
GIN search strategy for the systematic review of national and international guidelines for the diagnosis of OA	
1	Osteoarthritis
Guideline Central search strategy for the systematic review of national and international guidelines for the diagnosis of OA	
1	Osteoarthritis

(Continues)

Epistemonikos search strategy for the systematic review of national and international guidelines for the diagnosis of OA	
1	TI Osteoarth*
2	AB Osteoarth*
3	TI OA
4	AB OA
5	TI Arthrosis
6	AB Arthrosis
7	Guideline
8	Guidance
9	Diagnos* criter*
10	Recommendation*
11	S1 OR S2 OR S3 OR S4 OR S5 OR S6
12	S7 OR S8 OR S9 OR 10
13	S11 AND S12
BNI, EMBASE (HDAS) search strategy for the systematic review of national and international guidelines for the diagnosis of OA	
1	Degenerative arthritis
2	Osteoarthrosis
3	Arthrosis
4	Osteoarthritis
5	spondyloarthro*
6	1 OR 2 OR 3 OR 4 OR 5
7	Guideline*
8	recommendation*
9	"medical treatment guideline"
10	"Clinical Practice Guideline"
11	7 OR 8 OR 9 OR 10
12	6 AND 11
TRIP search strategy for the systematic review of national and international guidelines for the diagnosis of OA	
1	osteoarth*
2	OA
3	Arthrosis
4	1 OR 2 OR 3
5	Guideline
6	Guidance
7	Diagnostic criteria
8	recommendation*