Full Length Article

Effects of deprivation, ethnicity, gender and age on distal radius fracture incidence and surgical intervention rate☆

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A B S T R A C T

Introduction: Social deprivation has been shown to be associated with increased incidence of many types of fracture but the causes for this have not been established. The aim of this study was to establish if distal radius fracture was associated with deprivation and investigate reasons for this.

Method: Data was reviewed of 4463 adult patients who attended our Emergency Department over a four year period. The Index of Multiple Deprivation was used to measure deprivation for each patient. Modelling techniques were used to investigate the relationship between fracture rate and deprivation, gender, ethnicity and age.

Results: Distal radius fracture rate was higher for patients in more deprived quintiles. Mean age in the most deprived two quintiles was 54.4 years compared to 60.1 years in the least deprived three quintiles. Modelling showed important differences between ethnic groups. Deprivation was an independent risk factor for distal radius fracture only in white patients. Deprived white women had a lower second metacarpal cortical index than women of other ethnicities suggesting increased bone fragility. Being male is a risk factor for fracture when deprivation, ethnicity and age are taken into account. Incidence rate ratio of the least deprived quintile compared to the most deprived was 0.33 (95% CI: 0.30–0.37) for white men and 0.47 (95% CI: 0.44–0.49) for white women.

Conclusion: Effective interventions exist to prevent further fragility fracture and this work allows geographical areas at risk to be identified. Presentation with a distal radius fracture provides an opportunity to implement interventions. In the current economic climate resources are scarce and must be used prudently. Resources should be targeted to those at risk patients from deprived areas and preventative strategies put in place.

1. Introduction

Distal radius fracture (DRF) is an important cause of morbidity particularly among the elderly. 6% of women in the western world will have suffered a distal radius fracture by the time they are 80 [1]. Poor socioeconomic status is associated with higher prevalence of many diseases such as asthma and heart disease [2,3]. Social deprivation has been shown to be associated with many adult fractures including fractures of the hip and hand injuries [4–6].

Understanding inequalities in healthcare and which groups are at higher risk of injury can allow preventative mechanisms and prophylactic treatments to be put in place. Up to 45% of hip fracture patients describe a previous minimal trauma fracture [7]. Patients with a distal radius fracture have a greatly increased chance of hip fracture within the first year after injury [8]. Falls prevention, bone quality assessment and appropriate use of bone protective medication can reduce further fracture by 50% [7].

Several studies report increased fracture rate with deprivation but the reasons for increased fracture risk have not been established. Risk factors for osteoporosis such as smoking, alcohol, poor nutrition, raised

body mass index and low uptake of hormone replacement therapy treatment are likely to be found in areas of reduced socioeconomic status [9–11]. However, the association between deprivation and osteoporotic fracture is unclear. Jones et al. looked at over 60,000 patients who suffered fractures in Wales. They observed socioeconomic status was not a risk factor for the development of osteoporotic fracture in older people [4]. Other studies have reported similar findings.

The aim of this study was to establish if DRF was associated with deprivation and investigate the reasons for this. Further sub analysis is performed to investigate the influence of age, gender, ethnicity, osteoporosis and place of injury on DRF incidence. The effect of these factors on rate of surgical intervention is also investigated. This information can be used to identify at risk groups towards which preventative measures and resources can be targeted.

2. Patients and methods

A review was performed of all 4463 adult patients who attended Leicester Royal Infirmary with a distal radius fracture from January 2007 to December 2010. Emergency Department data was used to identify patients. Ethnicity is routinely collected for all patients who present to the department. Theatre books were then retrospectively reviewed to identify all patients who underwent operative intervention. 176 patients (3.9%) from outside Leicestershire were excluded from the study group as comparison with local population data would be inaccurate leaving 4278 for analysis. Patient demographics including sex, age, ethnicity, location of injury and postcode were recorded. A computer generated random sample of 100 patient's radiographs was assessed revealing accuracy of the ED data was 97%.

Radiographs of all patients who underwent surgical intervention (n = 618) were reviewed and a 10% computer generated random sample of those treated non-operatively (n = 367). Fractures of those who had surgical treatment were classified as intra or extra-articular. Intra-articular fractures are more complex injuries which are most often seen with high energy trauma and suggest a different mechanism of injury rather than a simple fall [12]. Bone density was calculated from the second metacarpal cortical width using the metacarpal cortical index (MCI). MCI is a measure of the combined width of the cortical bone in the metacarpals expressed as a ratio to the width of the shaft of the metacarpal. This method was chosen as almost all patients sustaining a DRF will have radiographs which demonstrate the second metacarpal. MCI has been reported in several studies to be a successful assessment of bone mass, bone quality, fracture displacement and a predictor of osteoporotic fracture [13,14].

Dorsal tilt was chosen as a measure of initial fracture displacement. Displacement and change in dorsal tilt is associated with underlying bone fragility [14,15]. Normal tilt is approximately 11° of volar angulation. To measure displacement the degree of tilt from the normal position of 11° was recorded for all radiographs reviewed. Displacement was measured on the first radiograph available following injury and before any intervention.

Radiographs were evaluated using digital imaging software by the primary author and two co-authors following a standardised teaching session. Inter and intra-observer correlation was calculated using the intraclass correlation coefficient (ICC) and demonstrated high reliability (MCI: inter-observer ICC 0.85, 95% CI 0.82–0.88, intra-observer reviewer 1: ICC 0.93 CI 0.86–0.96, reviewer 2: ICC 0.91 CO 0.84–0.95). We have previously published these findings for dorsal tilt [16].

The Index of Multiple Deprivation 2010 (IMD 2010) is a measure of multiple deprivation at the small area level. Small spatial areas called Lower Super Output Areas (LSOAs) are used to measure and compare deprivation in England [17]. There are 32,482 LSOAs in England with a mean population of 1500.

The Index of Multiple Deprivation 2010 is made up of seven domain indices. A score is given to each of these domains and combined to give an overall IMD score. A higher score reflects greater deprivation. LSOAs

Table 1
Number of DRF during the study period and incidence rate (per 100,000 of population at risk) by gender, ethnicity and age group seen in Leicestershire in each deprivation quintile from 2007 to 2010.

		White patients					
		Women			Men		
Deprivation	Age	Population	DRF	Rate	Population	DRF	Rate
Q1 (most deprived)	18–50	19,266	120	155.71	18,357	144	196.11
Q2	18–50	25,493	90	88.26	25,831	114	110.33
Q3	18–50	27,647	78	70.53	28,794	77	66.85
Q4	18–50	43,964	125	71.08	43,747	103	58.86
Q5 (least deprived)	18–50	52,782	124	58.73	51,894	125	60.22
Q1 (most deprived)	50 +	12,753	298	584.18	11,484	60	130.62
Q2	50 +	19,451	297	381.73	17,379	63	90.63
Q3	50 +	26,020	328	315.14	22,878	62	67.75
Q4	50 +	45,048	456	253.06	41,225	78	47.30
Q5 (least deprived)	50 +	55,295	636	287.55	50,431	103	51.06

		Patients of other ethnicity					
		Women			Men		
Deprivation	Age	Population	DRF	Rate	Population	DRF	Rate
Q1 (most deprived)	18–50	15,705	28	44.57	16,516	55	83.25
Q2	18–50	18,137	61	84.08	18,262	74	101.30
Q3	18–50	8390	20	59.59	8218	40	121.68
Q4	18–50	7640	21	68.72	7087	30	105.83
Q5 (least deprived)	18–50	7061	20	70.81	6419	28	109.05
Q1 (most deprived)	50 +	5396	69	319.68	4838	27	139.52
Q2	50 +	8115	95	292.67	7535	42	139.35
Q3	50 +	3983	61	382.88	3842	18	117.13
Q4	50 +	2890	41	354.67	2858	16	139.96
Q5 (least deprived)	50 +	2586	42	406.03	2626	9	85.68

are then ranked on this score from 1 to 32,482 with rank 1 being the most deprived area and highest IMD score. These rankings are split into 5 equal quintiles with quintile 1 being the most deprived.

Leicestershire and Rutland contains 606 LSOAs. Our unit is the only hospital to treat distal radius fractures in the region. Postcodes were used to link each patient to their respective LSOA with its assigned IMD 2010 score, rank and quintile. Accurate post code data was recorded for all patients so IMD score and quintile was available for every patient in the study group. Proportion of wrist fracture patients from each quintile were compared to total proportion of people in each quintile for the whole region. Patients were further stratified by age and compared to total number of people in the region within that age group. Some further analysis was performed by grouping patients by age of 18 to 49 years and 50 years and over. This age stratification was chosen as bone mineral density has been shown to remain stable until 50 years of age and therefore differentiate between fractures in younger patients with good bone quality and older patients with fragility fractures [18].

A generalised additive model (GAM) was used to investigate the relationship between deprivation rank with MCI and dorsal tilt. This model was chosen for these continuous variables after comparison with other non-linear regression techniques using cross validation and Bayesian information criterion.

Poisson regression modelling techniques were used to investigate the relationship between fracture rate and deprivation, gender, ethnicity and age. Models were constructed assessing variables against
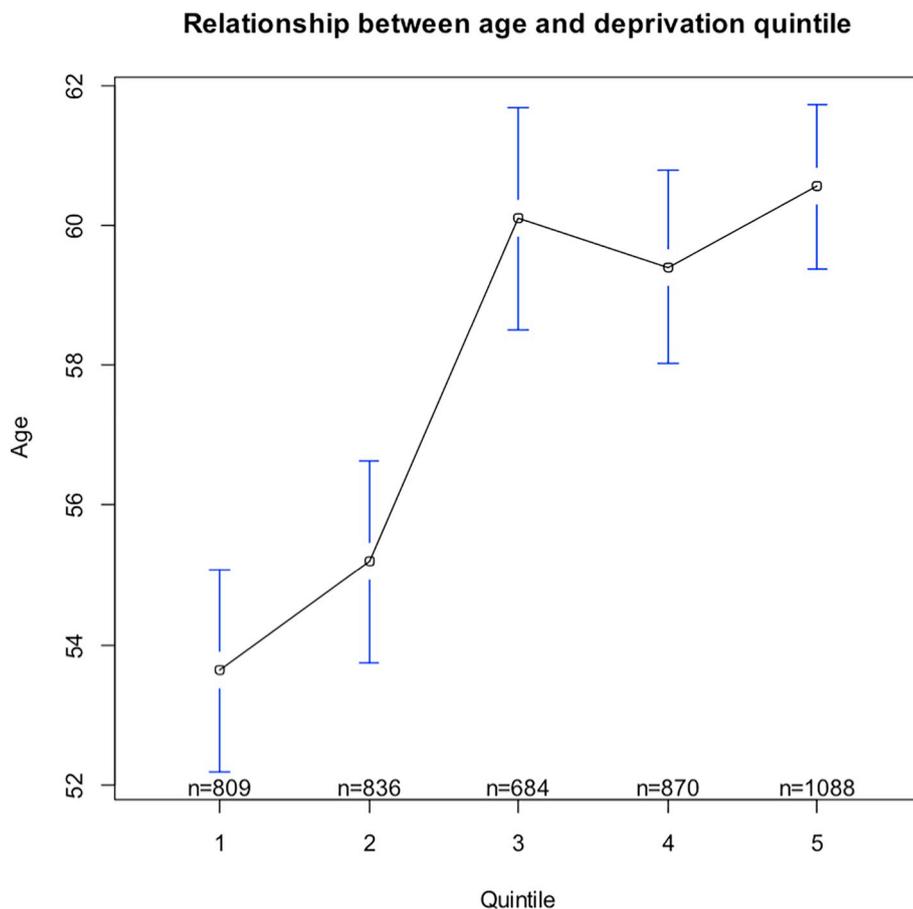
Relationship between age and deprivation quintile

Fig. 1. Mean age with 95% confidence intervals for DRF patients in each IMD quintile.
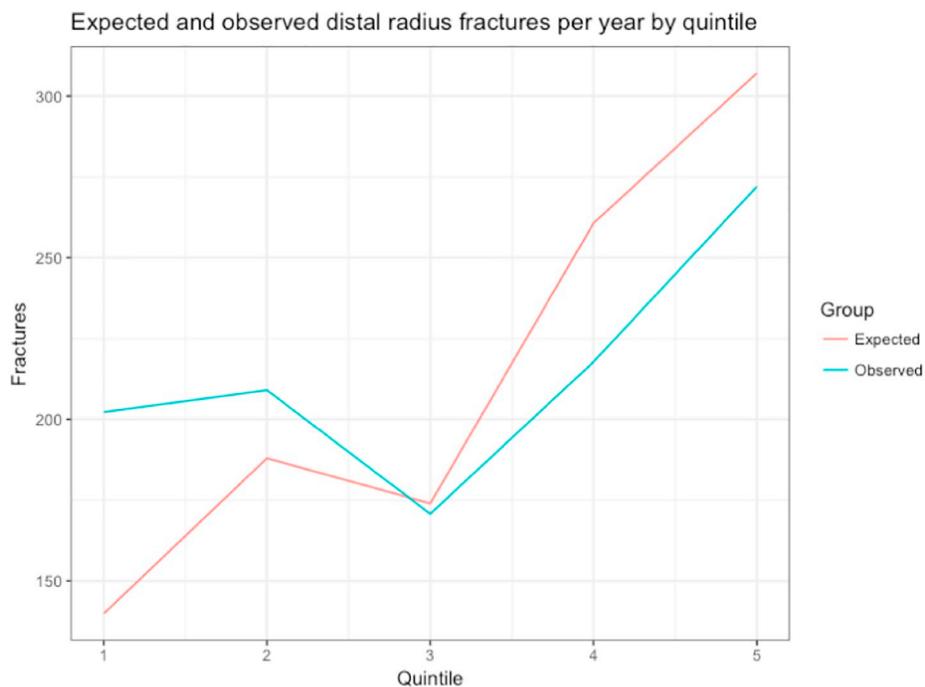

Fig. 2. Comparison of the expected and observed number of DRF seen in Leicestershire in each deprivation quintile from 2007 to 2010.

number of fractures, with an offset of the log of the population. This gives individual p values for each data item to demonstrate any significant variation from expected along with magnitude and direction of the change. Forward selection was used to select the most appropriate model, identify interactions and prevent over dispersion. Expected number of fractures, if deprivation does not influence rate, was estimated using the overall fracture rate calculated from the total number of fractures observed and total population at risk during the study
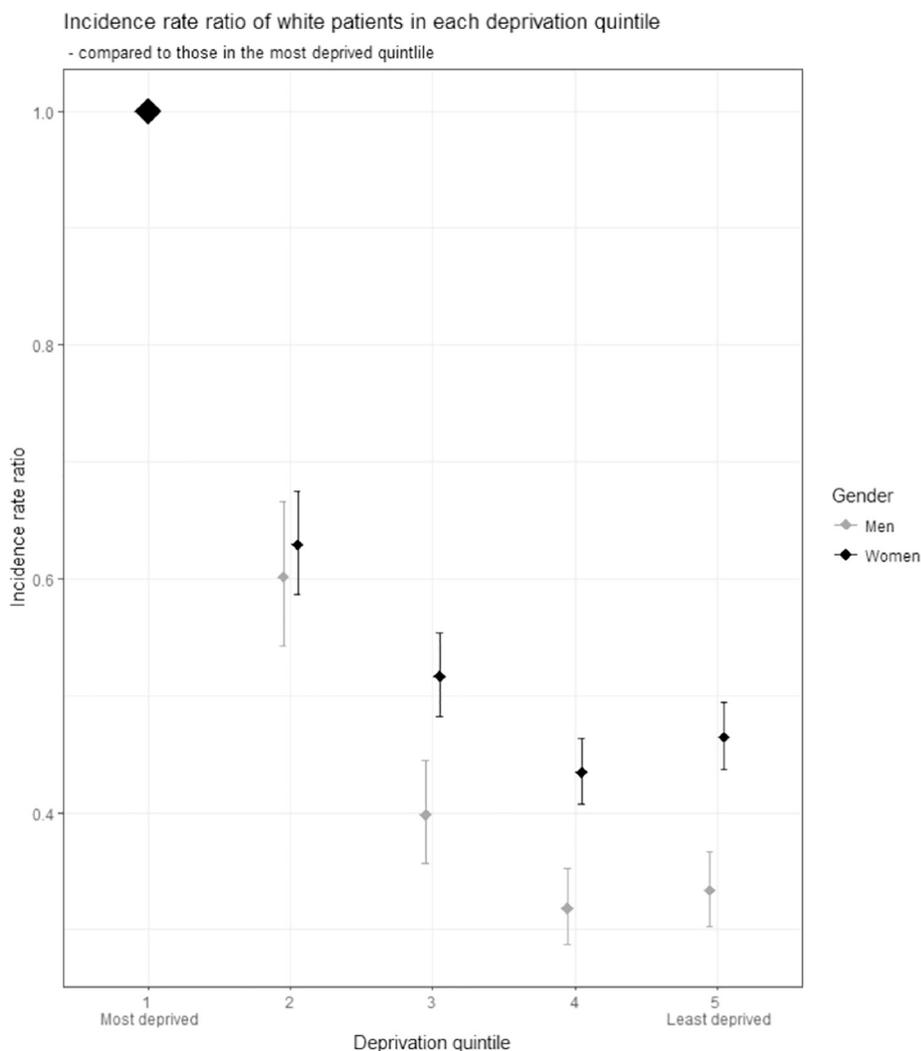
Fig. 3. Incidence rate ratio for DRF of white patients split by gender in each IMD quintile compared to those in the most deprived quintile.

period. This rate was applied to the population size of each quintile to give the expected number of fractures if rate is the same irrespective of deprivation quintile. The Kruskal-Wallis test was used to compare non-parametric data and the Chi-squared test to compare categorical data. Comparison of parametric data was performed using a *t*-test. Statistical analysis was performed with R. Local audit approval was obtained.

3. Results

DRF rate was higher for male and female patients in more deprived quintiles (Table 1). Mean age of patients in the most deprived two quintiles was 54.4 years compared to 60.1 years in the least deprived three quintiles ($p < 0.001$) (Fig. 1). More fractures than expected were seen in the two most deprived quintiles and less than expected in the least two deprived quintiles (Fig. 2). Deprivation seems to have most effect at the extremes of deprivation with minimal difference between observed and expected fractures in the median quintile.

3.1. Regression results

Further analysis was performed investigating the effect of age, gender and ethnicity with deprivation. Poisson regression model testing initially showed poorly fitting models with a significant interaction between ethnicity and all other factors (age < 0.001, gender < 0.001, deprivation < 0.001) indicating important differences between the

ethnic groups. Further regression was therefore carried out separately for the ethnic groups which improved the fit of the models.

Regression modelling of white patients ($n = 3481$) only showed fracture rate was associated with increased deprivation, age 50 years and over ($p < 0.001$) and male gender ($p = 0.010$). Model testing revealed a significant interaction between deprivation quintile and gender ($p < 0.001$) This interaction was therefore added to the final model and separate results produced for men and women per quintile. Incidence rate ratio of the least deprived quintile compared to the most deprived was 0.33 (95% CI: 0.30–0.37) for men and 0.47 (95% CI: 0.44–0.49) for women (Fig. 3).

The regression model demonstrated no association with fracture and deprivation for patients of other ethnicities ($n = 797$). There was no interaction between gender and deprivation ($p = 0.743$) suggesting similar results for men and women. Fracture risk was higher in males ($p < 0.001$) and patients aged 50 years and over ($p < 0.001$) (Fig. 4). The model was repeated with South Asian patients only as they were the largest other ethnic group ($n = 629$). Similar findings were noted with no association between fracture risk and deprivation but higher risk for males ($p < 0.001$) and patients aged 50 years and over ($p < 0.001$).

3.2. Radiographic analysis

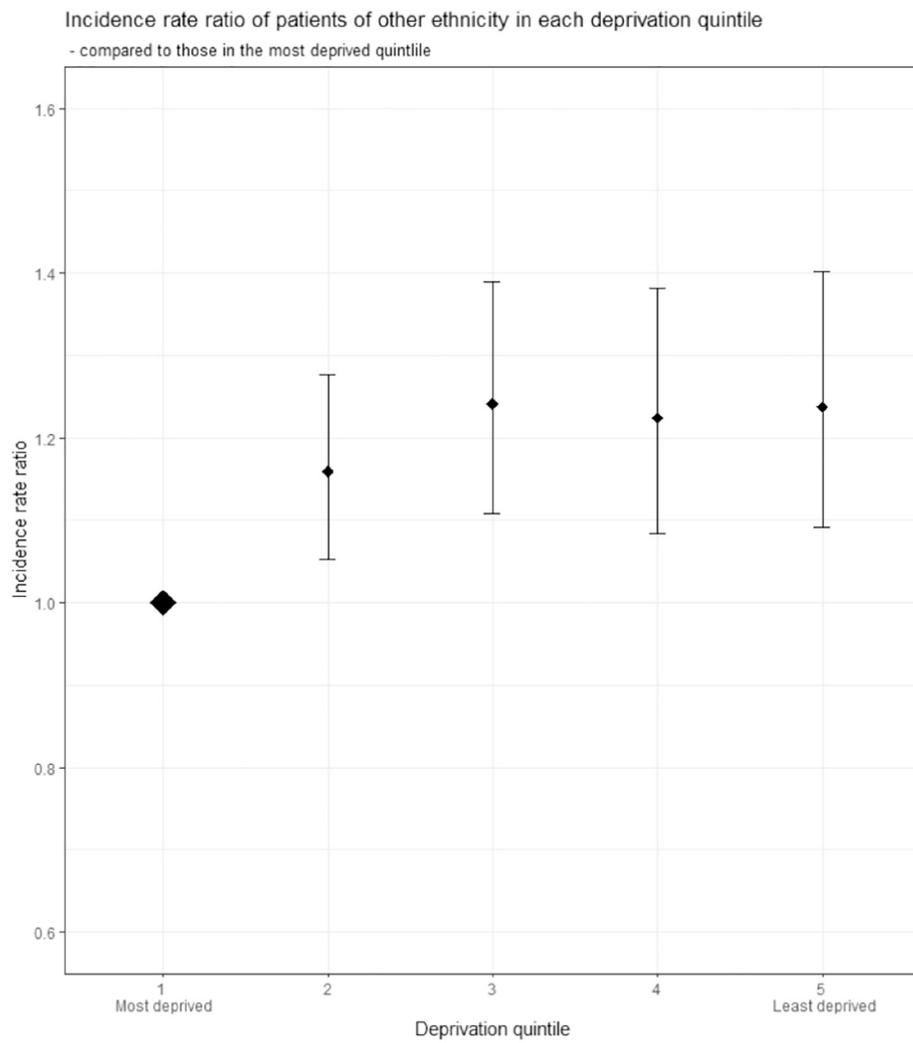Analysis of all radiographs reviewed and IMD rank showed no

Fig. 4. Incidence rate ratio for DRF of patients of other ethnicity in each IMD quintile compared to those in the most deprived quintile.
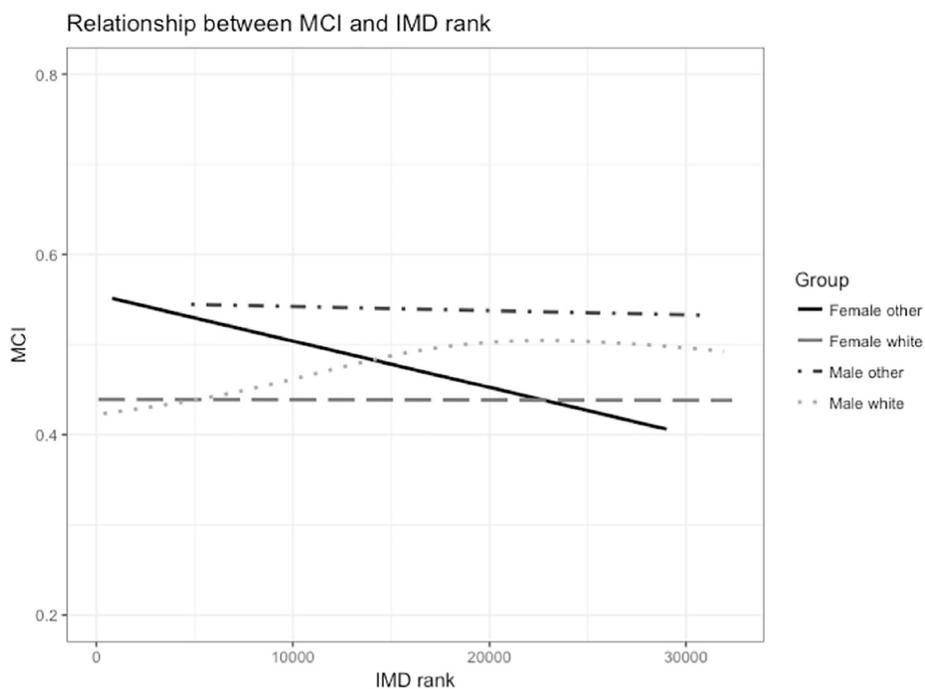

Fig. 5. Generalised additive model relationship between IMD rank (1 = most deprived) and MCI for patients aged 50 years and over by gender/ethnicity subgroup.

Table 2
Results of each gender ethnicity subgroup from the generalised additive model investigating relationship between IMD rank and MCI.

Group	Mean MCI	Mean IMD rank	N	p value
Female other	0.49	18736	50	**0.004**
Female white	0.43	11217	382	0.951
Male other	0.54	18930	25	0.839
Male white	0.48	12311	94	**0.034**

Table 3
Results of the comparison of mean MCI between the two most deprived quintiles (Q1–2) and the three least deprived quintiles (Q3–5) for each gender ethnicity subgroup.

MCI	Q1–2 mean	N	Q3–5 mean	N	p
Female other	0.52	31	0.46	19	**0.008**
Female white	0.44	117	0.44	265	0.734
Male other	0.55	16	0.53	9	0.753
Male white	0.44	26	0.50	68	**0.001**

relationship between deprivation and MCI (p = 0.139, n = 888) or post injury dorsal tilt (p = 0.08, n = 879). Further subgroup analysis was then performed by age group, gender and ethnicity (Fig. 5).

No relationship between dorsal tilt and IMD rank was seen in any of the subgroups. Increasing age was associated with reduced MCI (p < 0.001) but differences between ethnic groups persisted when age was taken into account (p = 0.003).

In patients aged over 50 significant trends were seen for females of other ethnicity and white males. Females of other ethnicity had higher MCI in areas of lower IMD rank indicating more deprived areas (n = 50, p = 0.004) (Fig. 5, Table 2). In the two most deprived quintiles their mean MCI was higher than white females in the same quintiles (Q1/2 other; MCI = 0.52, n = 31, Q1/2, white; MCI = 0.44, n = 117, p = 0.0001) and higher than females of other ethnicity in the three least deprived quintiles (Q3–5 other; MCI = 0.46, n = 19, p = 0.0078) (Table 3).

White males had lower MCI in more deprived areas (n = 94, p = 0.034, Table 2). In the two most deprived quintiles (Q1/2 white; MCI = 0.44, n = 26, Q1/2, other; MCI = 0.55, n = 16, p = 0.001) their MCI was lower than males of other ethnicity in the same quintiles and lower than white males in the three least deprived quintiles (Q3–5 white; MCI = 0.50, n = 68, p = 0.008) (Table 3).

In patients aged under 50 years no relationship was seen between MCI and IMD rank in any of the subgroups.

3.3. Surgical fixation

Patients who underwent surgical fixation (n = 618) were compared with the total group who sustained fractures. A regression model demonstrated no relationship with deprivation quintiles suggesting no difference in deprivation related to treatment. Patients aged under 50 years were less likely to undergo surgery (IRR 0.571, CI 0.408 to 0.798, p = 0.001). There was no association with gender (p = 0.391). White patients were more likely to undergo surgical intervention (IRR 1.737, CI 1.139 to 2.648, p = 0.010). This finding was seen in both age groups (under 50; p < 0.001, 50 and over; p = 0.002).

Patients with intra-articular fractures (p = 0.057) and those who sustained injuries outdoors (p = 0.075) showed a tendency towards surgical fixation but this did not reach statistical significance.

Male gender was associated with intra-articular fracture (p = 0.024). Injuries outdoors were strongly associated with the younger age group (p < 0.001). There was no relationship between intra-articular fracture and any deprivation quintile.

4. Discussion

In this study we used the United Kingdom government official measure of deprivation (IMD2010) to investigate whether DRF rate is influenced by socioeconomic status. Deprivation was strongly associated with DRF in the whole population studied. Deprived patients sustained their injuries at an earlier age. Further regression modelling showed important differences between the ethnic groups. Increasing deprivation was an independent risk factor for DRF only in white patients. Incidence of DRF is higher in women but the model has shown that being male is a risk factor for DRF when deprivation, ethnicity and age are taken into account. Incidence rate in the least deprived quintile was a third of that in the most deprived for white men and almost half for white women.

In their study involving 11.3 million people using UK General Practitioner data Curtis et al. reported fracture rates by gender and IMD quintile [19]. They also found deprived men had higher risk of fractures. In men, the relative risk of vertebral, wrist and hip fractures increased with deprivation. No association between risk of wrist or hip fractures was seen in deprived women and vertebral fracture risk was reduced. They suggested that the difference between genders with deprivation was due to adverse lifestyle factors such as smoking, alcohol and poor diet which are seen more often in men than women [9–11]. Brennan et al. also noted a larger association between deprivation and fracture in Australian men [20]. Bhimjiyani et al. recently analysed data from 747,369 patients with a hip fracture in England and reported that deprivation is a stronger relative predictor of hip fracture incidence in men than in women [21].

Our regression analysis revealed significant differences related to ethnicity with increased deprivation not being associated with fracture risk in patients of other ethnicities. We believe our sample size is large enough that this is not a type two error and review of the rates by ethnicity and quintile do not show any trends suggestive of this for patients of other ethnicity. Curtis et al. also reported fracture rate by ethnicity. They found white patients had the highest fracture rate, it was lowest in black patients and intermediate for South Asians. Differences in height, body composition, bone architecture and bone mineral density between races have been demonstrated between ethnicities with black people having higher BMD [22]. White people are generally taller which increases fracture risk [23]. No analysis to investigate interactions between factors was carried out by Curtis et al. and they acknowledged that some data was incomplete with ethnicity unknown for 44% of patients with a wrist or forearm fracture.

Pearson et al. demonstrated a significantly higher bone mineral density of the heel in women from less deprived areas using the Jarman Underprivileged Area Score as a measure of deprivation [24]. Another large study in Wales calculated fracture rates by Townsend deprivation quintiles for 60,166 people [4]. They found that fracture incidence was significantly higher in areas with higher deprivation scores. However, this effect diminished with age and they concluded that socioeconomic deprivation does not appear to be a risk factor for development of osteoporotic fractures.

Overall we did not demonstrate a relationship between deprivation and osteoporosis using MCI and dorsal tilt as surrogate measures of bone fragility.

Further sub analysis of radiographic findings split by age, gender and ethnicity revealed interesting results. No differences were seen between the groups in the younger patients. Women of other ethnicity aged 50 years and over in the most deprived quintiles had higher MCI. This may help explain why an association with fracture and deprivation was not seen in those of other ethnicity. These findings may represent a deprived ethnic population who are still required to be active, and possibly in employment, who therefore maintain bone mineral density. The reverse was true for white men aged 50 and over in the most deprived quintiles who had lower MCI. This may help explain why deprivation increases fracture risk in white men yet has less effect on

women and patients of other ethnicity.

Regression analysis comparing those who underwent surgery to all of those who sustained a DRF allowed independent factors for fixation to be identified. Patients aged 50 years and over were more likely to undergo surgery which is most likely due to the increased rate of displaced fragility fractures. Deprivation did not influence fixation rate which supports the radiological findings showing no association between deprivation and displacement.

White patients were more likely to undergo surgical intervention (IRR 1.737, CI 1.139 to 2.648, p = 0.010). This was despite our radiographic analysis, which included all patients who underwent surgery, showing no difference in displacement between the ethnic groups. The reasons for this are likely to be complex and beyond the scope of this study but an important research question has been identified. Cultural beliefs, family support systems, functional demands and language may play a part but bias must be considered. Unconscious bias is part of normal cognitive processing where a person's subconscious prejudicial beliefs or unrecognized stereotypes influence their responses. Surgical decision making is understood to be particularly vulnerable to unconscious bias and is well described in many surgical specialties including orthopaedics [25].

A strength of this study is the use of a government measure of deprivation applicable to a small geographical area to provide accurate results. This can be compared with other studies who use IMD data. Only one region was investigated but our overall results are conclusive and likely to be applicable to the rest of the UK. Postcode and ethnicity data was available for all patients. Most other studies investigating deprivation have come from the same unit with an overwhelmingly white population [26–28]. In our population we have a large ethnic mix allowing the opportunity to investigate the effects of ethnicity.

Limitations include that information regarding mechanism of injury, comorbidities and risk factors for osteoporosis was not available for all patients so was not included. Data was recorded prospectively then retrospectively analysed. Non-white patients were grouped together as an 'other' ethnicity category. Four fifths of these were South Asian so the results are largely applicable to this group. The proportion of white people and those of other ethnicity in our region is broadly similar to other cities although we have a higher proportion of South Asian residents. Our region overall is one of the least deprived in the UK but the city itself has large areas of high deprivation so we expect we have a large enough sample size from quintiles 1 and 2 to gain meaningful findings. After sub analysis of radiographs the number of other ethnicity radiographs reviewed was relatively small (n = 73) although we believe this should still produce useful results. 176 (3.9%) patients were excluded as they were from outside the region. It seems unlikely that this number of patients, or potentially a similar number from Leicestershire having treatment elsewhere would significantly affect results.

Leicestershire and Rutland has a population of 1,017,697 people with 132,301 people living in the most deprived quintile [29]. 889 patients suffered wrist fractures from this quintile over 4 years giving an incidence rate of 168 fractures per 100,000 population per year. In a city the size of London with a population of 8,308,400 people of which 2,176,801 live in the most deprived quintile this would equate to 3657 wrist fractures from this group alone per year.

This is the first study to carry out regression analysis including ethnicity and deprivation as factors to investigate their influence on fracture rate. We have demonstrated a strong association between distal radius fracture and deprivation. Potential reasons for this related to bone health, gender and ethnicity have been proposed and further research questions established. Effective interventions exist to prevent further fragility fracture and this work allows geographical areas at risk to be identified [30]. Education and programs to improve bone health in younger deprived patients and specific falls prevention for older patients may be beneficial. Presentation with a distal radius fracture provides an opportunity to implement interventions. In the current economic climate resources are scarce and must be used prudently. Resources should be targeted to those at risk patients from deprived areas and preventative strategies put in place.

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