Translational Medicine: What Orthopaedic Perspectives and Challenges Does the Mapping Technology?

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Translational medicine:What orthopaedic perspectives and challenges does the mapping technology?

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ABSTRACT

Background Translational medicine（TM）is a bridge between basic science and clinical medicine by translating new knowledge, mechanisms and technologies generated by basic science research into new ways of preventing, diagnosing and treating disease. The purpose of this study is to systematically review the literature concerning the two-dimensional and three-dimensional mapping technology (MT) for fractures in orthopedics, to clarify what perspectives MT offers and the current challenges in TM.

Methods A systematic review was conducted according to PRISMA guidelines. We systematically searched the PubMed, Scopus, IEEE Digital Library, Web of Science database and references of relevant studies, from the establishment of the database through December 2020, for any and all data regarding the application of fracture MT in orthopedics, (including upper limbs, lower limbs, spine, and pelvis). We then made a systematic summary of these research results.

Results A total of 2777 articles were retrieved, and 28 articles met the inclusion criteria: 26 were retrospective studies of using fracture MT and 2 were prospective studies using of fracture MT. The application of fracture MT in orthopaedics was as follows: upper limbs (n=10, 35.71%), lower limbs (n=17, 60.71%), thoracolumbar spine (n=1, 3.58%). Article subjects included: how fracture mapping guided preoperative planning (n = 12, 42.86%); illustration of how the characteristics of fracture line distribution helped surgeons identify specific types of fractures (n=9, 32.14%); and how fracture MT illustrated fracture morphology and guided clinical treatment (n=7, 25.00%).

Conclusion Today, we need a new generation of researchers: 'translational scientists' who are able to transfer ideas from basic research to clinical science. MT is a better technology to describe the morphological classifications of fractures compared to traditional methods, but its clinical application is still limited. Thus, much further research is needed to determine the potential advantages of this new technique in clinical application or practice. If possible, guidelines are needed to facilitate the development of MT with regard to the additional costs and time constraints required for the developing this technic.

Keywords Three or two-dimensional mapping . fracture line map . fracture. systematic review

Introduction

Translational Medicine(TM) is still a buzzword in the medical field today. Given the growing impact of scientific discoveries, TM was originally described as the "marriage" of basic and clinical science [1,2]. What defines TM? The answers to this question remain unresolved and controversial, but its overall character is: "the effective translation of new knowledge, mechanisms and technologies resulting from advances in basic scientific research into new ways of preventing, diagnosing and treating disease, with benefits for improving health [3].

Nowadays, Due to the increase in traffic accidents, not only has the number of various injuries increased, but many of them have become increasingly complex [4], making the classification of fractures more and more complex as well. Mediouni et al.[5] explain how to align with the progression of fractures complexity using 3D technology. But for most surgeons, many classifications are cumbersome and inaccurate. The question arises: how can I better classify this type of fracture? Is this a good classification? Fracture MT is a new type of digital TM that is important for understanding the morphology and mechanism of fractures [6]. Fracture patterns involving the complex anatomy of the major and surrounding structures involved in orthopedics can now be assessed with the use of MT [7]. Through fracture MT, surgeons can more accurately anticipate fracture patterns by superimposing fracture lines with zones of comminution and articular involvement. This provides previously unavailable mechanistic insights [8], more clearly illustrates the location and frequency of fracture lines, and helps to identify specific fracture patterns [9]. The two-dimensional or three-dimensional MT of fractures can also help surgeons to better understand the mechanical characteristics of these fractures, improving surgeons' preoperative diagnosis, preoperative planning, and execution of surgical strategies [10],[11]. The growing number of surgical applications MT affects makes it essential to analyze this new technology and to assess the value of present and potential applications.

Currently, there is a lack of evidence-based data in the medical literature, particularly in systematic reviews, on surgeons' recommendations for the use of fracture MT. The purpose of this study is to provide, based on existing evidence, proof of the value of MT in the classification of fractures and related injuries, to summarize the present status of the application, to clarify what perspectives MT offers and the current challenges in translational medicine.

Material and Methods

Main Research questions

The primary research questions of this review were as follows: What is the new perspective of two-dimensional and three-dimensional MT in the application of fractures? What are the current challenges for MT in TM?

Design and search strategy

This systematic review was designed, undertaken, and reported based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[12]. We made a thorough, comprehensive review of PubMed, Scopus, IEEE Digital Library, and Web of Science database and references of relevant studies articles on the application of MT in orthopedics. Only English documents from the origin of the database through December 2020 were considered. The list of references was reviewed to identify other potentially relevant research, including any research that dealt with fracture MT for orthopedic fractures (including upper limbs, lower limbs, spine, and pelvis). Inclusion and exclusion criteria applied to articles identified in the literature are shown in Table 1*(Note: An appendix of all tables and picture were supplementary information section)*.

Eligibility criteria

Inclusion criteria

1. All levels of evidence

2. Written in the English language

3. Studies on humans

4. Two-demensional or three-dimensional techniques are applied to fractures (e.g. upper limbs, lower limbs, spine, and pelvis)

Exclusion criteria

1. Review articles, protocols, commentaries, case reports

2. Basic studies

Data extraction

The study selection process was conducted independently by 3 researchers. If a study passed an initial screening based on the title and abstract review, the full text was retrieved and reviewed in detail to determine if the study met inclusion and exclusion criteria. The decision to include or exclude the study was made based on a group consensus. Data were extracted from studies that met the above-mentioned inclusion/exclusion criteria independently by the 2 reviewers. Data extraction was verified by an third reviewer. The following data were extracted from each study: author, year of publication, site of fracture, MT, and fracture characteristics.

Data analysis

The summary statistics indicating the number of data extracted from the individual studies was performed using counts, frequencies, and percentages[13].

Results

Study screening

A total of 2777 articles were retrieved, Pubmed(1277), Scopus(n=899), IEEE Digital Library(n=233) ,Web of Science(n=368). After removing duplicatesand irrelevant studies, 28 studies were identified for further full-text assessment. Using PRISMA methodology, the literature was screened via the flowchart shown in Figure 1. The fracture MT was first reported by Armitage et al.[14] in 2009, and then again by Cole et al.[15], who applied it to pilon fractures in 2013. In recent years, MT applications used in orthopedics have shown an increasing trend year by year. Details of the increase are shown in Figure 2.

Characteristics of included studies

The included 28 studies were conducted in 9 different countries, and some of the studies were international collaborative studies. The two most representative countries are China (n = 12, 36.36%) and the United States (n = 11, 33.33%), followed by Australia (n = 3, 9.09%), Turkey (n = 2, 6.07%), Germany (n=1, 3.03%), the Netherlands (n=1, 3.03%), France (n=1, 3.03%), Switzerland (n=1, 3.03%), Canada (n=1, 3.03%). About the application of two-dimensional or three-dimensional MT in orthopedics: the included studies mainly dealt with fractures of upper extremities, lower extremities, the spine, and the pelvis, of which tibial plateau fractures accounted for the largest proportion. The upper extremities consisted of general scapular fractures (n=2, 7.14%), radial head and olecranon fractures (n=3, 10.70%), distal radius fractures (n=3, 10.70%) and navicular bone fractures (n=2, 7.14%). The lower limbs consisted of the pelvis and acetabulum fractures (n=3,10.70%), intertrochanteric femur fractures (n=4, 14.28%), a Hoff fracture (n=1, 3.60%), a patella fracture (n=1, 3.60%), tibial plateau fractures (n=5, 17.84%), Pilon and posterior malleolus fractures (n=3, 10.70%), and finally a thoracolumbar fracture (n=1, 3.60%). Details of the proportions are shown in Figure. 3. Supplementary display tables 2, 3, and 4 show upper extremity, spine and pelvis, and lower extremity research results and related fracture characteristics.

Data Synthesis

To clarify what perspective MT offers in TM. Among the included studies, the most often reported application was that fracture MT can guide preoperative planning (n=12, 42.86%). In this regard, several surgeons said that fracture MT could optimize preoperative planning, such as surgical approach and setting specificity fixation structure [8], [10], [11], [14], [15], [16], [17], [18], [19] ,[20], [21]. Others said that the understanding of fracture patterns through the MT of fractures leads to the possibility of the development of new classifications and implant designs[22]. Many others thought that two-dimensional or three-dimensional fracture MT can illustrate the characteristics of fracture distribution and help surgeons predict specific types of fracture injuries (n=9, 32.14%), and lastly some found that MT can also predict the number of fracture lines and the direction of fracture lines, which may have a certain impact on treatment[23]. Two-dimensional MT and heatmap technology can help surgeons predict the distribution of fracture lines related to specific injury types[24]. In the treatment of distal radius fractures, special attention should be paid to these small fragments[25].

A study showed that fracture MT improves the awareness of traumatic vertebral fractures, and helps increase the chances of follow-up research and helps in clinical decision-making [6], Furthermore, studies have shown that age and gender have a significant impact on the frequency of femoral intertrochanteric fractures and the distribution of fracture lines[26]. The information gained about the distribution characteristics of fracture lines may be helpful to clinical practice and help clinical decision-making[27],[28],[29],[30].

In the remaining studies (n=7, 25.00%), it was found that fracture MT can also clarify fracture morphology and guide clinical treatment. There is a study which showed that, in most patients with intra-articular fractures showing partial displacement of the radial head, the distribution and location of the fracture lines are not related to the overall specific pattern of traumatic elbow joint instability, suggesting a common fracture mechanism that involves the anterolateral part of the radial head [9] Another study used 3D CT to describe the morphology of an acute fracture and correlated comminution and displacement with the type of fracture. The dorsal ridge and volar waist need prudent assessment, especially in waist fractures [31].

A similar fracture MT shows that acute scaphoid fractures mainly occur in the middle third of the bone, and tend to divide the scaphoid bone into two halves, according to the size of the fracture fragments [32]. There are also research reports using fracture MT to enable elderly patients with acetabular fractures to bear weight earlier after initial hip replacement [33]. Using fracture MT to study the treatment of the tibial plateau, modern locking plate positioning can effectively treat 72% of lateral platform fractures and 91% of medial platform fractures [34]. In the latest study, the classification of the tibial plateau was studied using fracture MT. From the perspective of three-dimensional mapping, the four-column and nine-segment classification methods have a higher degree of matching compared with the commonly used classification methods [13].

Discussion

With the development of TM, clinical results could be improved with more awareness concerning the applied and translational characteristics of basic research. Today, due in large part to increased computing power and new technologies for high-quality data generation. MT has gradually evolved into an increasingly important technique for the study of the morphological classification of fractures, facilitate fracture classification, aid preoperative planning and guide decisions about clinical treatment.

Previous scholars have reported that the development of TM has brought us great convenience. For example, 3D simulation becomes an effective tool to help surgeons to understand many complex problems [35,36]. Precise tumor localization, the tumor removal process good cutting accuracy to achieve satisfactory tumor cell-free margins by simulated instruments [37-39]. Artificial intelligence and machine learning technologies have begun to change how we deliver healthcare [40], these revolutionary computational methodologies can transform the way clinicians help patients in the clinic and also enhance the way scientists develop new treatments and diagnostics in the laboratories [41,42]. As there are many classifications of complex fractures that are cumbersome and inaccurate, Mediouni et al.[5] also explain how to align with the progression of fractures complexity using 3D technology, virtual 3D may be useful for visualizing and planning treatment of fractures, potentially leading to more accurate and efficient reductions, and may also be an effective educational tool [43]. To our knowledge, this is the first systematic and comprehensive analysis of the application of MT in the field of orthopedics. First of all, we note that fracture MT is often regarded as an observational tool to study the distribution of fracture lines. In the included study, the MT has the value of guiding preoperative planning. For example, the prevalence of articular comminution suggests that traditional surgical approaches for exposure of simple fracture lines may need modification for improved visualization of the articular surface at the focal point of the zone of comminution [44]. However, as described by Letenneur et al. [45], the subjective classification of fracture types may not be satisfactorily consistent among observers, which may have a certain subjectivity in the reduction of fracture fragments, which will also affect the design of the preoperative surgical approach. However, the increased complexity of fracture patterns will make the current fracture MT difficult to apply, and the results will be more difficult to interpret. Nevertheless, the frequency MT helps subdivide fractures and is a simple way to describe them by involved areas, which improves the comparability of fractures in studies and could potentially enable a standardized descriptive method and helps for planning the operative procedure. The use of MT shows it's more reliable than other similar studies and can be used as a guide for preoperative planning, which is confirmed by Doornberg et al. [46] and Hall et al. [47]. Similarly, through the MT, observed the fracture line is concentrated at the intersection between the safety zone and the danger zone, and the surgical approach can be recommended during the operation [8]. However, due to the lack of a precise intraoperative instrument to assess the positions of the screws, it still relies on the surgeon's experience and skill level to reach the proper position and decrease iatrogenic complications. Most of the CT data used to study the MT comes from the first-level trauma center. Therefore, the types of fractures related to high-energy injuries may be over-represented, and superimposing the fracture line into representative models is another limitation of this technique to achieve accurate research. In theory, the fracture pattern may be different in low-energy and high-energy injuries [30], which also affect the direction of preoperative planning. Meanwhile, due to the anatomical structure is standardized before the fracture line is analyzed using the MT, the potential variability of function, anatomical structure, and injury mechanism was ignored, which may also limit the promotion of research results.

Surprisingly, all studies reported the benefits of MT. the positive effects reported provide the support to recommend the use of MT as an adjunct to the study of fracture classification in clinical practice. MT to determine the distribution of fracture lines can help surgeons predict specific types of fractures and guide clinical treatment. For example, fracture lines of tibial plateau occur frequently in the transition zone with marked changes in cortical thickness. According to the 3D heat mapping of MT, the four-column and nine-segment classification had a high degree of matching as compared to the frequently used classifications [13]. We note that in most studies, the process of virtual reduction, the existing MT can only show the distribution of the fracture line on the surface, but not the displacement and compression of the fracture block, so the accuracy is difficult to estimate objectively. However, the development of this MT must also take into account many other factors, such as patients with a complete radiological assessment, a sufficient number of cases, complex operational skills, and so on. Therefore, it is a challenge to promote this MT in hospitals to gain clinical benefits. Indeed, MT requires specific software skills that most surgeons do not have, the operational difficulty of the software technology is a limiting factor. TM in orthopedics is hugely expensive and funding sources usually are already strained to the point that the use of available resources in academic research funding alone is typically not enough [48]. We also note that the overlay techniques for fracture MT seem to be outsourced to professional technicians, often using expensive and complex techniques when new and complex technologies are introduced into medical research and practice, the cost of implementation is often a concern, which also another factor limiting the current development of MT in the field of orthopedics. It's also surprising that few of the 28 studies included reported the use of MT for clinical treatment. In our view, this observation emphasizes that MT is still in its infancy in this surgical field. Finally, our findings show that the limitations of MT can explain why this technique is still rarely used in clinical guidance.

Nevertheless, in the long term, the use of fracture MT can change surgeons' understanding of fracture morphology, facilitate fracture classification, aid preoperative planning and guide decisions about clinical treatment. MT translates current basic scientific findings into clinical benefits. For the development of TM, clinical outcomes can become more aware of the applied and translational nature of basic research. Today, we need a new generation of researchers: 'translational scientists' who should be able to transfer an idea from basic science to clinical science for the betterment of patients. To promote effective translational medicine, academia must take the lead in creating an enabling environment for the first steps of translation. Meanwhile, Guidelines are needed to facilitate the development of MT with regard to the additional costs and time constraints required for the development. Much further research is needed to determine the obvious and potential advantages of this new technique in clinical application.

In our systematic review of the literature, there is a lack of information about fracture MT, which may be most of the authors are surgeons who are more concerned with the results than the details of the MT. This systematic review has some limitations that need to be mentioned. First, we did not retrieve unpublished studies, which may introduce some biases, although the quality and level of information provided in these studies may be problematic. Secondly, we only limit the language to English, which may lead to the deviation of the choice of language. Finally, we note that the conclusions of MT reports are most of the advantages, which may be due to publishing bias, and some authors or journal editors are reluctant to publish negative research results. In fact, collecting every research report is a time-consuming and laborious task. However, our researchers strictly try to record all the information available.

Conclusions and future directions

Today, we need a new generation of researchers: 'translational scientists' who are able to transfer ideas from basic research to clinical science. MT is a better technology to describe the morphological classifications of fractures compared to traditional methods, but its clinical application is still limited. Thus, much further research is needed to determine the potential advantages of this new technique in clinical application or practice. If possible, guidelines are needed to facilitate the development of MT with regard to the additional costs and time constraints required for the developing this technic.

List of Abbreviation

Translational medicine（TM）

Mapping technology (MT)

Declarations

Ethical approval: This is a systematic review, and therefore, IRB approval is not required.

Consent to Participate: Each author agrees to participate

Consent to Publish: Each author agrees to publish

Availability of data and materials : All data generated or used during the study appear in the submitted article.

Conflict of interest: The authors declare that they have no conflict of interest.

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Authors' contributions

Guang shi: writing, data collections

Wei Liu: data analysis, data collections

XiYu Cai and Xiuyun Su study design and revise

Note: Xiyu Cai and Xiuyun Su were co-corresponding authors. Guang Shi and Wei Liu made the same contribution to this paper

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Figures

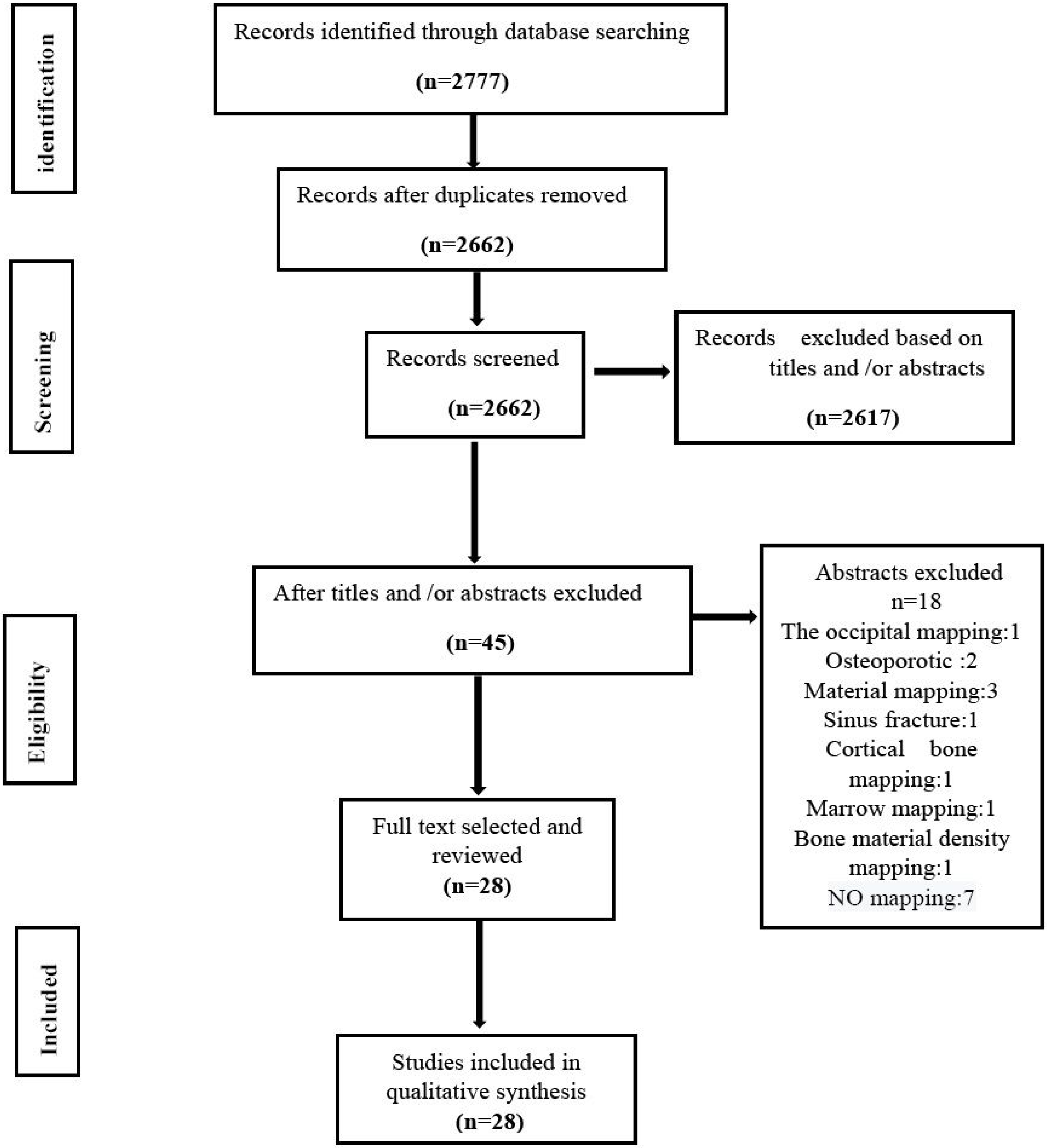

Figure 1

PRISMA flow chart of studies selection.

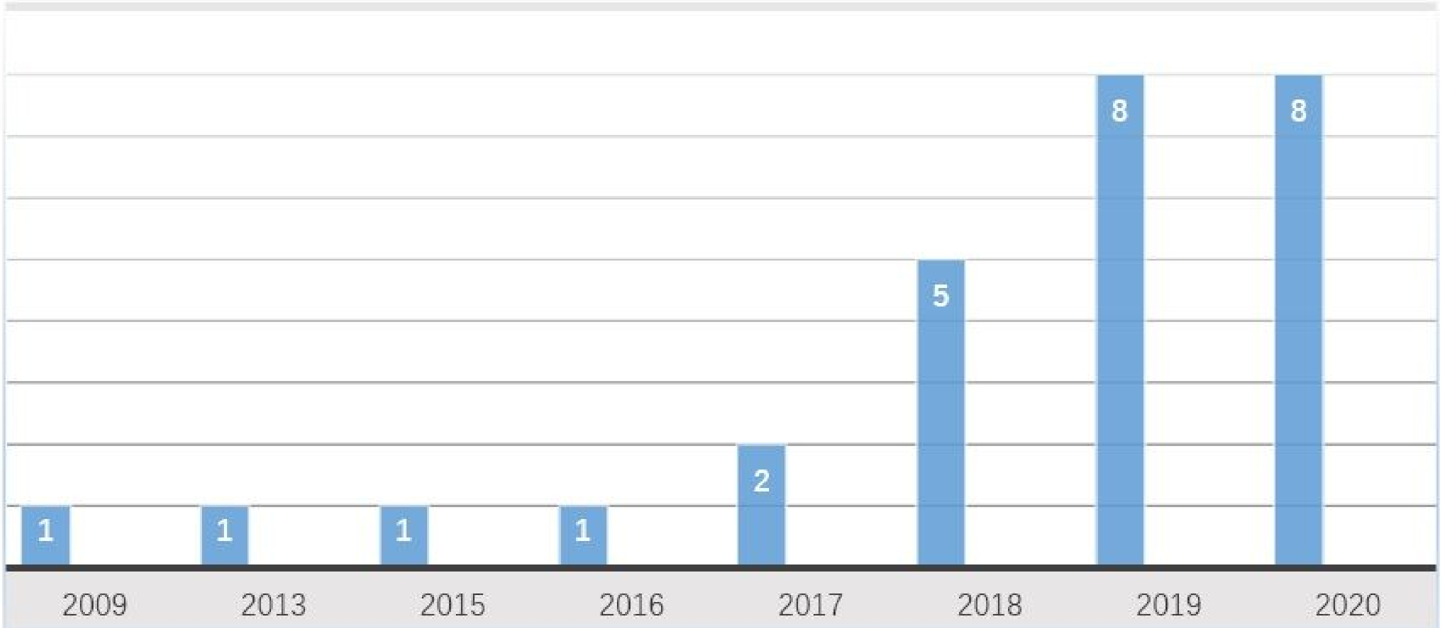

Figure 2

Overview of selected papers based on publication year

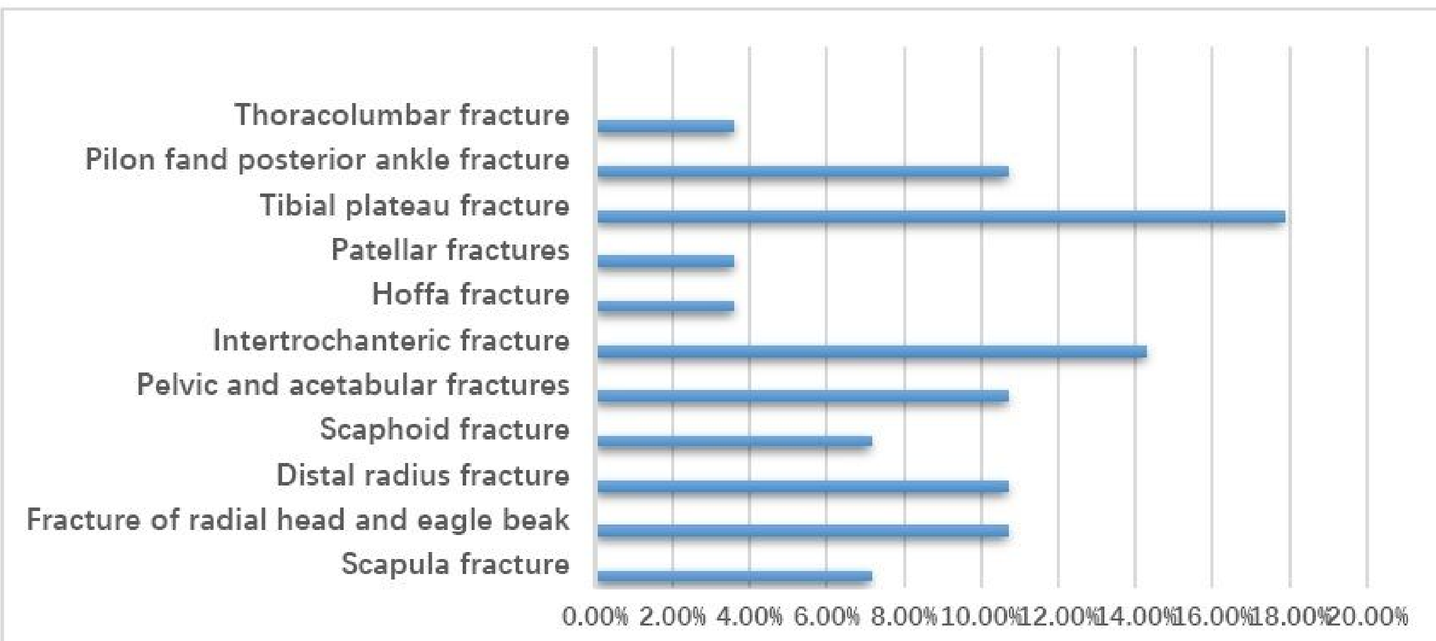

Figure 3

The fracture MT is applied to specific site

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- PRISMA2009checklist.doc
- table.pdf