The use of methylphenidate should be investigated further in mild traumatic brain injuries. The current available studies show evidence of improvement in patients with mild to severe traumatic brain injuries, but it is unclear if there would be any benefits for patients with milder forms of traumatic brain injury.[7–10, 13] Amantadine was also found to improve cognitive function, but did not show any difference in memory or attention. However, the study's sample size was small and a larger study investigating the use of amantadine in mTBI patients would help confirm these findings.[11]

The use of sertraline in patients with mild traumatic brain injury was found to have improvements in cognition, memory, and depression in the study by Fann et al.[12] However, Lee H et al.[13] found that the cognitive improvements of sertraline were not any better compared to placebo. A double-blind, randomized, placebo-controlled trial on the effects of sertraline on patients with mild TBI would help elucidate these findings.

The NMDA antagonist (Traxoprodil) was found to have no difference in effects on neurobehavioral outcomes or the speed of recovery.[14]

Levin HS et al.[15] investigated the use of CDP-choline in patients with mild traumatic brain injury in which he found greater reductions in post-concussional symptoms and improvements in memory. However, the number of patients in this study was small, and the author suggested a larger follow-up study should be performed. Such a study has yet to be carried out.

Donepezil was found to be beneficial in patients with mild to severe TBI.[16–18] However, these studies did not perform a separate analysis for patients with mild TBI. Therefore, a focused study investigating the use of donepezil in mild TBI patients would help confirm the benefits in attention, cognition, and memory.

Peptide treatments were found to be beneficial in cognition and memory.[19, 20] However, these studies were small and larger studies should be undertaken to confirm the results of these studies in patients with mild TBI.

Several studies investigated the use of pharmacological agents to treat a few symptoms following a mTBI. For treating the symptom of depression, serotonergic agents (sertraline, amitryptylin, milnacipran) and a dopaminergic agent (methylphenidate) were shown to be effective in treating post-concussive depression when measured by HAM-D scores.[12, 13, 21–24] Treating post-traumatic of amnesia with rosuvastatin was shown to reduce the length of the symptom; however, this study had a small sample size with only a fraction of the patients with mTBI.[25] A larger study should be performed with mTBI patients to confirm the effects of rosuvastatin. Modafinil was investigated in treating post-traumatic fatigue and was found to have no statically significant difference when compared to placebo.[27]

The use of corticosteroids in patients was recommended to not be used according to the CRASH trial results.[28, 29] However, when analyzing the mild TBI subgroup separately, there was no statistically significant difference in deaths in the use of corticosteroids at the two-week and six-month endpoints. A careful risk-benefit assessment should be made in advising the use of corticosteroids in patients with mild TBI.

The results of this systematic literature review have several limitations. Although the search was comprehensive, there may be articles that were not included in this search. The absence of these articles could lead to a bias in one drug intervention over another. Additionally, the studies that were included had heterogeneous outcome measures, causing the studies to be less comparable.

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Predicators of Complications Associated with External Fixators

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Introduction

External fixation is a surgical procedure used to treat a number of different bone pathologies. The method entails percutaneous insertion of pins or wires into a bone, and subsequent attachment to an external fame, in order to stabilize the bones to allow for healing. The concept of external fixation was first utilized by Hippocrates, although the technique was not popularized until the twentieth century.[1, 2] Numerous developments since then, including notable designs by Swissman Raoul Hoffmann and Russian Gavril Ilizarov, have led to the external fixator designs used today. Such designs include monolateral external fixators, ring external fixators, and hybrid fixators (which combine technology of both monolateral and ring designs.) External fixators are quite versatile in their use. They can be used to reduce open and closed fractures, arthodesis, limb lengthening, and repair of bone deformities. External fixation can be utilized alone as a definitive treatment, or as a temporary treatment to allow soft tissue healing before internal fixation[3] and have been used on bones of the upper and lower extremities, cervical and lumbar spine, mandible, and pelvis.[4–6] The benefits of external fixation include its versatility, relative ease of surgical application, ability to maintain the wound site for better healing, and allowance for early weight-bearing[1, 7] as well causing less disruption of soft tissue and blood supply compared with internal fixation or intramedullary nails, making them better for trauma settings or in patients with compromised healing abilities.[2]

Despite the many of advantages of external fixation, the method is not without potential problems with numerous complications having been described, most notably pin tract infections.[1, 8–11] Recent studies have reported rates of pin tract infections of up to 96.6%, although other studies show lower rates.[10] Other infections, such as chronic osteomyelitis, sepsis, or myiasis, may occur as well.[1, 10–14] Non-union or mal-union of the bones is another potential adverse effect of external fixators, as is development of iatrogenic fractures.[1, 15–18] Another common complication of external fixators is neurovascular damage. Neurovascular damage may manifest itself as a neurological deficit, reflex sympathetic dystrophy, compartment syndrome, deep vein thrombosis, fat embolism, or pseudo-aneurysm.[1, 3, 9, 14, 19–25] Additional complications observed in the literature include bone angulation, contractures, tissue necrosis, and hardware malfunction.[1, 12, 26–28]

Much research has been devoted to understanding the adverse effects of external fixation; however, there is currently a lack of consensus about what additional variables are associated with developing these complications. Most studies dealing with complications have mainly focus on the rates of complications and their treatment recommendations, while excluding mention of what other factors may place a patient at risk. For example, Ahlborg and Josefsson note that they observed such complications as secondary displacement requiring re-reduction, non-unions, additional surgeries due to carpal tunnel, tendon rupture, and reflex sympathetic dystrophy, but the authors do not give comment or explanation beyond the rates of each complication.[29] Other studies state factors that predict complications, but without sufficient evidence to support their claims.[1, 12] Some studies do show predictive factors for complications, but with too limited a scope, i.e. only certain indications for external fixation, certain anatomical locations, certain outcome measurements, or certain types of external fixator devices.[30–32]

This study aims to expand on the research that describes variables associated with complications of external fixation by providing a more comprehensive analysis than is currently found in the literature. Such variables may include patient demographics, injury type, intra- and post-operative care, patient behaviors, and presence of comorbidities. By discovering correlations between one or more variables and development of complications after external fixation, these variables may identified as risk factors that predict a bad outcome after external fixation.

Materials and Methods

After IRB approval for exempt status was obtained, a patient registry database was used to compile a list of patients who underwent surgical application of one or more external fixator to an upper or lower extremity at Temple University Hospital between the dates of January 1, 2006 and May 30, 2012. The CPT code 20690, associated with application of a

uniplanar external fixator, was used. Surgical application of external fixator devices by orthopedic surgeons at Temple University Hospital were included. This search generated an initial list of 153 patients. After removing patients for which adequate medical records could not be obtained, a list of 75 patients were eligible for the study. A data sheet was generated to document all parameters to be studied, as described below. Retrospective review of hospital electronic medical records of eligible patients was performed and findings noted in the data sheet.

Demographic data, defined as age, gender, race, and insurance status, was recorded. Details about the indication for external fixation was noted, including extremity and bone affected, associated injuries, and mechanism of injury. Specification of open or closed fracture was recorded as well, in addition to device manufacturer.

The authors documented preoperative, intraoperative, and postoperative care according to the following parameters. For preoperative care, the time between injury and external fixator application was recorded, as well as whether anticoagulants and antibiotic medications were given during this timeframe. Intraoperative care parameters recorded included time in surgery, tourniquet time, and whether pinholes were pre-drilled or hand-drilled. Also noted were details about the pins used by the surgeon, including their size, position, and number of pins. For postoperative care, the authors recorded length of hospital stay, frequency and agent of pin cleaning, whether physical therapy was given, time in external fixation, secondary treatments after external fixator removal, time between external fixation and secondary treatments, additional surgeries performed, and length of follow up.

Medical history and comorbidities were noted, as documented in subjects' medical records, including presence of diabetes mellitus (complicated or uncomplicated), rheumatoid arthritis, present systemic or local infection, HIV, renal disease, osteoporosis or osteopenia, depression, dementia, chronic vascular insufficiency, coronary artery disease, hypertension, hypothyroidism, lymphedema, or other diseases. MRSA history, history of disease in affected bone or joint, and BMI were also recorded, as were patient behaviors including smoking, and drug use. The authors recorded preoperative glucose levels as well.

Incidences of complications were recorded, as documented in patient charts. Infections were noted, including pin tract infection, osteomyeltis, myiasis, or other infections. The authors also documented incidence of ARDS, tissue necrosis, and purulent pin-site drainage. Bone-related complications were recorded, including nonunion or mal-union, heterotopic ossification, angulation, and iatrogenic fractures. Neurovascular adverse effects were noted, including neurologic deficit, reflex sympathetic dystrophy, compartment syndrome, deep vein thrombosis, fat embolism, or pseudoaneurysm. The authors documented both occurrence of complications at any point during follow up and complications that occurred during specific time frames. The authors defined these time frames as follows: 1) during external fixation; 2) after removal of external fixator before placement of additional treatment method; 3) after removal of external fixator and during subsequent treatment method; 4) after removal of both external fixator and subsequent treatment (or after removal of external fixator without subsequent treatment); 5) up to one week after external fixator application; 6) up to 30 days after external fixator application; 7) up to six months after external fixator application; 8) up to two years after external fixator application or to total follow up time (if follow up exceeds two years).

After data was collected, results were analyzed with the assistance of the Temple Biostatistical Center. Outcome variables were correlated with risk variables to screen for a risk or predictive relationship. The relationships found to have statistical significance ($p < 0.05$) and moderate or strong strength of correlation (Spearman correlation coefficient >0.5) were further studied using odds ratio estimates and slope regression estimates.

Results

In total, 75 uniplanar external fixators were applied to 75 patients (55 male, 20 female), with an average patient age of 43.6 (range 17–82). Fifty-nine patients had documented comorbid conditions at the time of external fixator application, with an average of 2.8 comorbidities per patient (of those who had one or more comorbidity). The most common comorbid conditions were hypertension (21 cases), obesity (BMI >30, 20 cases), asthma (13 cases), dyslipidemia (10 cases), diabetes mellitus (10 cases), and history of injury in currently injured site (seven cases). Twenty five of the external fixators were applied to treat factures in the upper extremity, while 50 were applied to the lower extremity. The most common site of injury was the distal tibia. The most common causes of injury were falls, followed by gunshot wounds and pedestrian-versus-auto accidents. The average time between injury and application of external fixator was 4.5 days, and the average length of hospital stay was 11.6 days. External fixators remained on fracture sites for an average of 51 days (range 2–439 days). The average length of follow-up was 14 months.

Table 1. Overall Comorbid Conditions

Comorbidity	Number of Cases	Average Per Case
Any comorbidity	59	2.8
Hypertension	21	
Obesity (BMI >30)	20	
Asthma	13	
Dyslipidemia	10	
Diabetes mellitus	10	
Prior injury	7	

Of the 75 cases, 59 developed one or more complication during the follow-up period (78.67%). Of those who developed complications, the average number of complications

was 2.4 per patient. The most commonly recorded complications were heterotopic ossification (16 cases), nonunion (15 cases), neurologic deficit (14 cases), tissue necrosis (11 cases), and pin tract infection (nine cases). Other complications of note that occurred in one or more cases included compartment syndrome, purulent pin site drainage, osteomyelitis, lipohemarthrosis, deep vein thrombosis, ARDS, angulation, and iatrogenic fracture.

Table 2. Overall Complications

Complication	Number of Cases	Average Per Case
Any complication	59	2.4
Heterotopic ossification	16	
Nonunion	15	
Neurologic deficit	14	
Tissue necrosis	11	
Pin tract infection	9	

Overall, patients with higher numbers of comorbidities were more likely to develop complications than those with fewer comorbidities. Specifically, for each additional comorbidity that a patient had, the risk of an increased number of complications developing within 90 days of application of external fixator increased by 1.5 times, adjusted for age, sex, and BMI. Furthermore, the number of complications that a patient develops at any time increased by an average of 0.24 for each additional comorbidity that a patient had.

While only three patients developed iatrogenic fractures, this complication was correlated with two specific comorbidities. Patients with a history of osteomyelitis were almost 37 times more likely to develop iatrogenic fractures than those without a history of osteomyelitis (odds ratio estimate 36.958). Similarly, patients with a history of sarcoidosis were almost 140 times more likely to develop iatrogenic fracture than those without a history of sarcoidosis (odds ratio estimate 139.985). Sarcoidosis history was also correlated with an increased incidence of pin tract infection (odds ratio estimate 18.285) and tissue necrosis (odds ratio estimate 13.778). A history of injury in the affected limb was correlated with purulent pin site drainage, with an estimated odds ratio of 16.00.

Discussion

Previous studies have shown very high complication rates associated with external fixation, and our study confirms that complications are quite common with this treatment modality.[1, 10] Our study also indicates that patients' comorbidities play a significant role in predicting complications that may occur during the postoperative period. Regardless of what medical conditions a patient has, more comorbid conditions may lead to more complications after external fixation. This suggests that patients' medical histories should be more closely assessed to determine if they are safe candidates for external fixation. If a patient has significant comorbidities, perhaps an additional treatment modality would be better indicated.

Our study indicates that sarcoidosis, osteomyelitis, and previous injury in the fractured limb may be problematic comorbid conditions for external fixation since they were associated with significant complication rates. This may be explained by the idea that osteomyelitis and other previous bone injuries cause weakened bone tissue that predispose it to fracture or infection when an external fixator is applied. Similarly, the systemic inflammation associated with sarcoidosis may predispose bones to structural damage and infection upon placement of an external fixator. Further research regarding the mechanisms by which these conditions may lead to external fixation complications is needed.

Limitations of the study include the small sample size and low statistical power. Because so many variables were examined with a small number of cases, there may be limitations on the reproducibility of statistical outcomes. For instance, only three patients had comorbid sarcoidosis and only two had history of osteomyelitis, so the calculated odds ratio estimates of these comorbidities associated with specific complications may be overestimates of their true associations. Additionally, all information was collected from electronic medical records, so errors in documentation may have occurred. Future studies, particularly of a prospective design, are warranted in order to more accurately gauge the risk factors of external fixation complications and determine causality.

Conclusion

According to our study, having multiple co-morbidities at the time of external fixator application may be correlated with higher rates of complications. Medical conditions of particular concern include osteomyelitis, sarcoidosis, and previous injury in the limb undergoing external fixation. Further research is needed to assess these risk factors and complications in more detail.

Table 3. Risk Factors for Complications

Variable	Outcome	Odds Ratio Estimate	Slope Regression Coefficient	p Value
Number of comorbidities	Total number of complications		0.2377	0.0307
Number of comorbidities	Number of complications within 90 days	1.492		0.0313
Osteomyelitis history	Iatrogenic fracture	36.958		0.0381
Sarcoidosis	Iatrogenic fracture	139.985		0.0018
Sarcoidosis	Pin tract infection	18.285		0.0240
Sarcoidosis	Tissue necrosis	13.778		0.0398
Prior injury	Purulent pin site drainage	16.000		0.0041

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Medical Student Research Project

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Disparities in Internet Usage by Orthopaedic Outpatients

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Abstract

The "digital divide," identified in the US, established that internet access has lagged behind among patients of lower income and of certain ethnic groups.

Expansion of internet access over the past decade is analogous to the recent proliferation of smartphones, extending online use to specific patient groups, affecting access to online health information, and potentially revolutionizing this divide. The 28-question survey, completed by 100 orthopaedic outpatients, evaluated associations between patient age, ethnicity, income, or education level, and their access to the internet, use to obtain information about their medical condition, privacy concerns during this online research, and patient use of mobile phones as a primary means of internet access. The internet was used by 57% of orthopaedic outpatients in our urban population, internet access decreased with age, and increased with income and education level, which were consistent findings from similar studies. Despite the inability to identify an association between ethnicity and internet access in this patient population, fewer Latinos sought information about a personal medical condition than did Caucasians or African Americans. Amongst patients who used their mobile phone as a primary method for online access, 74% were African American or Latino, significantly greater than 26% Caucasians. This deviation in online smartphone use in conjunction with the lack of disparities in internet use found between ethnic groups insinuates that mobile phones have provided ethnic minorities with greater internet access, and thus made a probable contribution to the narrowing of the "digital divide" amongst the races in our population of orthopaedic outpatients.

Introduction

The technological revolution triggered by the rapid growth of the internet has provided patients with unprecedented access to medical information.[1] Access to the internet by adults in the US has improved greatly over the past decade, and the internet is becoming the preferred source for patients to acquire health information.[2] According to a survey conducted in 2010, 74% of adults in the US use the internet and 80% of them searched for health-related topics, which equates to 113 million Americans that obtain health information on the internet, or 59% of all adults in the US.[3] Within the field of medicine, it was found that as many as 75% of patients had access to the internet themselves or through a close friend or family member.[4] This widespread use of the internet by patients to access health information has progressively broadened and reshaped the role of physicians and health care providers, while it has the potential to enhance patient satisfaction and participation in health care.[5]

Previous studies have evaluated the use of the internet in the specific clinical setting of orthopaedic outpatient practices. A research group at the University of Michigan found that internet use by orthopaedic patients had increased from 20% in 1998 to 46% in 2003.[6] Of internet users in a study of over 500 orthopaedic patients at the University of Pennsylvania, 47% of patients who accessed the internet reported that they had used the web to retrieve health or medical information.[7] More explicitly related to orthopaedic information, 20% of patients in a community outpatient practice used the internet to research their current orthopaedic diagnosis.[8] A patient, or a surrogate responder for the patient, was more likely to search for the patient's pediatric orthopaedic diagnosis on the internet if the condition was chronic like scoliosis (54%), as compared with a much lower rate (18%) in acute conditions like fractures.[9]

The majority of consumers who searched for health information on the internet began their inquiry by using a search engine, and 58% of people implicated that the information obtained from their search had an impact on a decision regarding treatment of an illness or condition.[10] While health information on the internet has clearly influenced the health decisions made by patients, only one of 57 pediatric orthopaedic patient education articles available on the AAOS and POSNA web sites had the recommended readability grade level.[11] Other prevalent concerns that pertain to health information on the internet, particularly because confidentiality is imperative in maintaining the integrity of a patient's medical care, include the security and privacy of personal information when health information is accessed online. Analysis at

an orthopaedic outpatient clinic found to a statistically significant degree, that patients with lower annual household incomes were more apprehensive about both privacy and security when they went online.[12] The internet has the ability to eliminate barriers to access to information, but only if online material can be accessed, read and understood by many different types of users.[2]

Despite the rapid growth of the internet and the penetration of the internet into the health care industry in recent years, internet access has lagged behind among lower socioeconomic classes and certain groups of ethnic minorities, a phenomenon that is known as the digital divide.[13] This concept was studied in a hand surgery outpatient clinic, which showed that as household income increases, there was a greater likelihood of owning a computer, more time was spent on the internet, and patients more frequently found that information on the internet was trustworthy, secure, and private.[12] A similar study conducted in an elective spinal surgery outpatient population in Ireland showed that increasing age, higher education level, and possession of health insurance were all significantly associated with access to the internet.[14] Although in recent years, the online population has become more representative of the larger US population in terms of race, age, income, and level of education,[15] uncertainty remains as to whether the "digital divide" remains prevalent in access to the internet and in the use of health care information by the orthopaedic outpatient population. Furthermore, the soaring popularity of smartphones in the general US population, illustrated by an increase in adults who own a smartphone from 35% in May 2011 to 46% in February 2012, has changed internet access particularly for groups that have traditionally been on the other side of the "digital divide."[16] This report described that amongst smartphone users, ethnic minorities, less educated individuals, and those with lower household incomes were more likely to identify their mobile phone as the primary source for accessing the internet. It is our suspicion that this phenomenon has improved our own patients' access to the internet, many of whom are ethnic minorities and of low income, perhaps narrowing the "digital divide."

Although disparities between ethnic groups in the general US population have been identified in home computer ownership, work computer access, and internet use,[17] no medical research to date has explored the influence of ethnicity on the internet use by these orthopaedic patients in an urban outpatient setting. This study, therefore, aims to evaluate differences in patient demographics that may influence internet access in urban orthopaedic outpatients, determine if mobile access has narrowed the "digital divide" in our patients, and explore the variation in the patient use of the internet based on their ethnic background.

Materials and Methods

Adult patients aged 18–89 years old who were being treated for an orthopaedic condition at an outpatient orthopaedic clinic of an urban academic medical center between June and August 2010 were given the opportunity to participate in the study. The 103 patients who consented to participate were administered a survey in a private setting with a laptop and secure internet connection. The survey was administered via Surveymonkey.com. Incarcerated persons were excluded from this study. In addition, two patients that completed the survey were under the age of 18 and one patient did not submit a finished survey. These three patients were also excluded and, consequently, the remaining 100 patients were included in our analysis. The institutional review board approved this investigation.

A single questionnaire consisting of 28 questions was used (Appendix 1). Eight questions pertained to the patient's background information and included: age, gender, ethnicity, primary language, annual household income, level of education, type of health insurance, and the condition for which the patient was seeking treatment. The remaining 20 questions were designed to ascertain information from the patients regarding their internet use in the following categories:

1. General internet access: use within the past year, modes of access, average use per day, main reasons for use, and primary search engines used.
2. Internet use pertaining to the patient's health: had the patient used the internet to find out about a personal health condition, did the patient or anyone else use the internet to find out about the condition that the patients was currently visiting the clinic for, and which websites did the patient or the surrogate use to obtain the information about this condition.
3. The influence of health information obtained from the internet on the patient's interaction with the doctor: did the patient plan on discussing what they learned on the internet with their doctor, would the patient mention to the doctor that the question or topic resulted from an internet search, and did they believe that doctors appreciate it when patients use the internet to find out medical information.
4. The patient's experience and opinions of the health information that they found on the internet about their condition: was it helpful, clear, trustworthy, difficult to understand; did it help the patient make a decision about their health, and did the information bring up things that the patient wanted to discuss with their doctor.
5. Internet privacy: did this concern the patient, and did it affect the patient's use of the internet to look up personal health information.

The survey enabled patients to skip or leave questions blank if they desired. The questions regarding the patient's means for accessing the internet, main reasons for using the internet, primary search engines used, and the sites used to obtain health information, allowed patients to select all applicable choices. Five participants reported multiple education levels, and the highest level that they selected was exclusively used in our analysis. Three patients that selected

Appendix 1

THIS IS AN ANONYMOUS SURVEY. YOU MAY SKIP QUESTIONS THAT YOU DO NOT WANT TO ANSWER.

Have you used the internet within the past year?

☐ Yes ☐ No

What is the condition for which you are currently seeking treatment?

☐ Fracture ☐ Arthritis ☐ Deformity
☐ Sprain/strain ☐ Spinal condition ☐ Other

Please select all the ways that you access the internet.

☐ Computer at home ☐ Computer at a library or other public building
☐ Computer at work or school ☐ Mobile phone

On average, how many hours do you spend on the Internet each day? _____ Hours

What are the main reasons for using the internet? You may select more than one answer.

☐ E-mail/Communication ☐ News ☐ Entertainment
☐ Social networking ☐ Shopping ☐ Health/medical information

What search engines do you primarily use? You may select more than one answer.

☐ Google ☐ AOL Search ☐ Ask.com
☐ Yahoo ☐ Bling ☐ Alta-Vista

Have you ever used the internet to find out about a personal health condition?

☐ Yes ☐ No

Did you use the internet to find out information about the condition you are here for today?

☐ Yes ☐ No

Did anyone use the internet to find out information about the condition you are here for today?

☐ Yes ☐ No

Which sites did you or someone else use? Please select all choices that apply.

☐ WebMD ☐ CDC Health Topics A to Z ☐ HealthAtoZ
☐ Health Central ☐ AAOS.org ☐ Other
☐ WrongDiagnosis.com ☐ Wikipedia

Did you or do you plan on discussing anything that you learned in your internet search with your doctor?

☐ Yes ☐ No

Do you think you will mention that the question or topic came up as a result of an internet search?

☐ Yes ☐ No

Do you have concerns about privacy when using the internet?

☐ Yes ☐ No

Does privacy affect your use of the internet to look up personal health information?

☐ Yes ☐ No

What is your current age? _____ Years old

Gender ☐ Male ☐ Female

Ethnicity

☐ African American ☐ Latino/Hispanic ☐ Caucasian
☐ Asian ☐ Native American ☐ Other

Primary language ☐ English ☐ Spanish ☐ Other

Annual household income

☐ <$10,000 ☐ $18,001–35,000 ☐ $50,001–100,000
☐ $10,001–18,000 ☐ $35,001–50,000 ☐ >$100,000

Education level

☐ No high school ☐ GED ☐ Some high school
☐ Some college ☐ High school graduate ☐ College graduate

Health insurance

☐ Medicare ☐ Health Partners ☐ Private
☐ Medicaid ☐ Keystone Health ☐ None

Continued on next page

Appendix 1 ***Continued***

FOR THE FOLLOWING QUESTIONS, PLEASE SELECT THE STATEMENT THAT BEST FITS YOUR EXPERIENCE ABOUT USING THE INTERNET TO FIND INFORMATION ABOUT YOUR MEDICAL CONDITION.

The information was helpful.

☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

The information was clear.

☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

The information was trustworthy.

☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

The information was difficult to understand.

☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

The information helped me to make a decision about my health.

☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

The information brought up things that I wanted to discuss with my doctor.

☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

I think doctors appreciate it when patients use the internet to find out medical information.

☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

GED for their level of education were excluded from analysis based on education, and one patient who chose other for their ethnicity was likewise excluded from analysis based on race. Annual household income levels that were originally ascertained in the survey based on levels of less than $10,000, $10,001 to $18,000, $18,001 to $35,000, $35,001 to $50,000, $50,001 to $100,000, and greater than $100,000, were then grouped into three categories of less than $18,000, $18,000 to $50,000, and 50,001 to greater than $100,000. This was done on the basis that results were similar amongst the groups that we combined, which was also noted and performed by Parekh in a study conducted at a hand surgery outpatient clinic.[12] In a similar manner, the age of each patient was grouped into three categories consisting of patients less than 50 years old, patients aged 50 to 65, and those who were older than 65, as Baker had previously done successfully in a study of elective spinal surgery outpatients.[14]

Statistical analysis was performed using the JMP5 statistical software. Differences in the categorical data was assessed using the chi squared test, and differences that were found to have a $p < 0.05$ were considered statistically significant.

Results

Internet Access

Of 100 patients attending the orthopaedic outpatient clinic in the urban setting of Philadelphia, 57% had used the internet within the past year. Internet use decreased as age of the patient increased (Figure 1). Younger patients less than 40 years of age were more likely than middle-aged patients of 40 to 50 years old to have used the internet ($p < .001$), and this trend of greater internet use in the younger population was even more striking when compared to use in elderly individuals 60 years or older ($p < .001$). Other demographic variables that were found to significantly influence patient internet use were household income and level of education (Table 1). Patients with an annual household income of less that $18,000 were less likely to have accessed the internet within the past year, as compared to those making between $18,000 and $50,000 ($p < .01$) and those making $50,001 to greater than 100,000 ($p < .05$). An analogous finding was seen in patients that did not graduate high school, who were found to have accessed the internet within the last year significantly less than patients who graduated high school ($p < .05$), attended some college ($p < .001$), and patients who graduated college ($p < .001$). In contrast however, we were unable to demonstrate a statistically significant difference in access to the internet between Caucasian, African-American, and Hispanic patients in our study population.

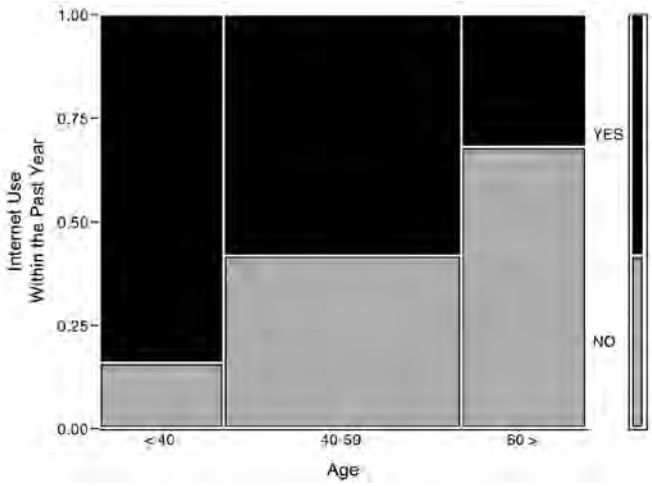

Figure 1. Orthopaedic outpatients who had used the internet within the past year in different age groups of patients.

Table 1. Internet Use Within the Past Year

	No	Yes	p Value	Odds Ratio	95% CI
Age			.001		
<40	16% (4)	84% (21)	—	—	—
40–59	42% (20)	58% (28)	.03	0.27	(.08–0.89)
>60	68% (17)	32% (8)	<.001	0.09	(.02–0.35)
Ethnicity			.66		
Caucasian	37% (9)	63% (15)	—	—	—
African American	41% (21)	49% (30)	.76	1.17	(.43–3.16)
Latino/Hispanic	50% (12)	50% (12)	.38	.60	(.19–1.89)
Annual Household Income			.002		
<$18,000	58% (26)	42% (19)	—	—	—
$18,000–$50,000	21% (6)	79% (22)	.002	5.02	(1.71–14.76)
$50,001–>$100,000	18% (2)	82% (9)	.02	6.16	(1.19–31.82)
Highest Level of Education			<.001		
No high school diploma	77% (20)	23% (6)	—	—	—
High school graduate	50% (18)	50% (18)	.03	3.33	(1.09–10.24)
Some college	10% (2)	90% (18)	<.001	30	(5.36–167.93)
College graduate	13% (2)	87% (13)	<.001	21.67	(3.78–124.19)

Internet Use for Medical Purposes

In the outpatient clinics of our orthopaedics department, 65% of patients had used the internet in the past to find out about a personal medical condition. More explicitly, of these 57 patients, 19% reported that they had used the internet to find information regarding their health condition that was being addressed at the current orthopaedic visit, and in a similar question with 78 responses, 14% of patients stated that someone else had used the internet to obtain this information for the patient. A statistically significant association ($p = .03$) was found in our analysis between patient ethnicity and use of the internet to find information about a personal health condition (Table 2). Hispanic patients were found to have researched their medical condition on the internet less frequently than Caucasian or African American patients (Figure 2). The difference between Hispanics and Caucasians was nearly, but not statistically significant ($p = .09$), however there was definitively less use of the internet by Hispanics to obtain information about a personal health condition, as compared to African American patients ($p < .01$). In contrast, patient internet use to find out about a personal health condition was not significantly different based on age, or annual household income in this urban orthopaedic outpatient population. The final aspect of this survey that pertained to access of the internet for medical information was used to assess the prevalence of privacy concerns when patients searched the internet for information on their medical condition. Of the 52 patients who responded, 62% expressed that they had concerns about privacy. Despite finding that African Americans (67%) and Hispanics (64%) more frequently expressed a concern for privacy on the internet than Caucasians (50%), this was not a statistically significant disparity between the ethnic groups. In the same way, we were also unable to demonstrate a significant association between annual household income and patient outlook on privacy while searching the internet for information about their medical condition.

Table 2. Use of the Internet to Find Out About a Personal Health Condition

	No	Yes	p Value	Odds Ratio	95% CI
Ethnicity			.03		
Latino/Hispanic	67% (8)	33% (4)	—	—	—
Caucasian	33% (5)	67% (10)	.09	.25	(.05–1.25)
African American	23% (7)	77% (23)	.008	.15	(.04–0.66)

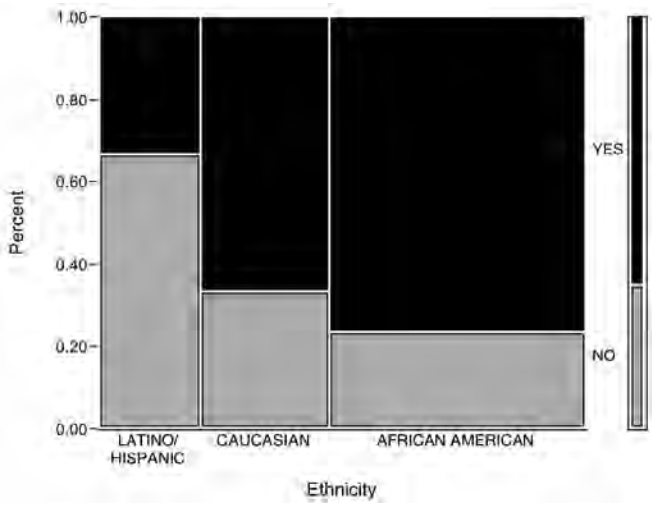

Figure 2. Patients who have used the internet to research a personal medical condition based on patient ethnicity amongst orthopaedic outpatients.

Characteristics of Patient Internet Use

Although part of this study relied on patient characteristics, which primarily included income, ethnicity, and smartphone use to assess disparities in internet access and use amongst orthopaedic outpatients, the survey also examined general elements of internet use in this population as a whole. Patients who attended orthopaedic clinics in this urban setting averaged three hours of internet use per day. Of these 56 responders that addressed their amount of internet use, the vast majority predominantly accessed the internet by

using a computer at home (84%), but there was also a large group of patients (48%) who used a mobile phone as their primary means for internet access (Figure 3). The main reason patients used the internet was for e-mail or communication (85%), while only 33% of the 55 participants that responded to this question listed health or medical information as a main reason for use. In comparison, other main reasons these patients used the internet included 53% for entertainment, 49% for news, and 40% for shopping. Internet use and the process of obtaining information online is frequently initiated through search engines, and an additional evaluation of these 55 patients determined that Google was the most widely used search engine (80%), although the majority of patients used Google, Yahoo (56%), or both.

Discussion

This study was designed to evaluate the level of internet access within a sample of patients attending orthopaedic outpatient clinics of an urban academic medical center and to determine patient demographics that predict characteristics of patient internet use.

The internet was accessed within the past year by 57% (95% CI: 47–66%) of patients in our survey, which was to some extent less than the 2010 national average (74%) of adults using the internet in the US.[3] Highly probable explanations for this observed disparity are the annual household income and education level of individuals living in the urban population of Philadelphia. Our study population contained 39% (95% CI: 30–50%) of patients with an annual household income less than $10,000, and only 7% (95% CI: 3–15%) with an annual household income greater than $100,000. This varies from the 2011 US population assessed by the US Census Bureau to have 8% of citizens with an annual household income less than $10,000 and 21% with greater than $100,000.[18] An additional aspect of our study population that contributed to this discrepancy in internet access was education level, most notably 27% (95% CI: 19–36%) of patients failed to obtain a high school diploma and only 15% (95% CI: 10–24%) had graduated college, as compared to 13% and 37% respectively, which are characteristic of the US population.[19] Because of demographic disparities between our patients population and US citizens in general, including household income and education level, comparing patient internet access found in our study with a similar urban population of orthopaedic outpatients would be of greater analytic utility. In doing this, the 57% of patients that we found to have access to the internet was identical to the percentage reported in a 2004 study of orthopaedic patients at the University of Pennsylvania, which consisted of a survey population that profoundly mirrored ours in many of these aspects. Significant characteristics of internet access by these patients pertain to outpatient orthopaedic care, including the use of the internet to obtain general health or medical information and to research a personal health condition or orthopaedic diagnosis. In 2006, 64% of internet users searched online for a specific disease or medical condition.[10] A similar result from our study demonstrated that 65% (95% CI: 52–76%) of orthopaedic outpatients had at some point used the internet to find out about a personal health condition. There was also marked consistency between the 19% (95% CI: 11–31%) of patients found in our study who used the internet to find information about the orthopaedic condition for which they were currently attending the clinic, and the 21% of orthopaedic outpatients in another Philadelphia practice who used the internet to learn about their orthopaedic condition.[7]

Household income, education level, and age had previously been shown to predict internet access in the US population, as well as in surveys of orthopaedic outpatients. Based on the income of US citizens, 57% of people earning less than $70,000 use the internet, as compared with 95% of individuals earning greater than $75,000.[20] This "digital divide" amongst households with annual income inequalities was also depicted in a population of orthopaedic patients, where a statistically significant increase in internet use was associated with increased household incomes in groups earning <$18,000, between $18,000 to $50,000, and $50,000 to greater than $100,000, which was determined by the hours per day patients at an outpatient hand surgery clinic used the internet.[12] Using these same income groupings in our study, we were able to reassert this trend, as a statistically significant increase in patient internet access was identified when annual household income increased. Education level is also a contributing factor to the "digital divide," illustrated in a 2012 survey that showed

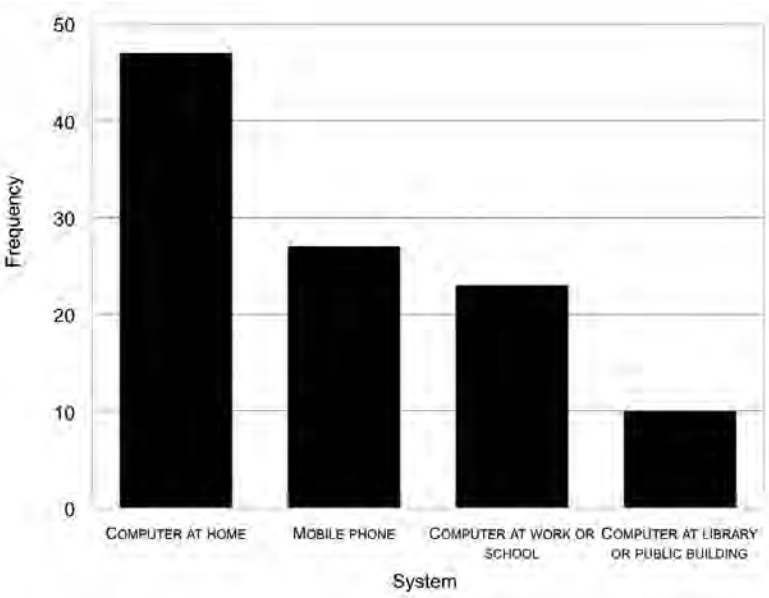

Figure 3. The primary means used by orthopaedic outpatients to access the internet.

43% of US citizens with no high school diploma were internet users, while 71% of high school graduates, 88% of individuals with some college education, and 94% of college graduates used the internet.[16] While the significance that education level has in influencing internet access had been studied in an elective spinal surgery outpatient population in Ireland, the structure of the European education system is considerably different, and no study to date has evaluated if the education level of orthopaedic outpatients predicts their internet access in a US medical survey. Our study in the urban population of Philadelphia illustrated statistically significant greater use of the internet as the level of education achieved by the orthopaedic outpatient increased, which was determined by individually comparing patients with no high school diploma to high school graduates, patients who attended some college, and college graduates. An additional factor contributing to orthopaedic outpatient internet access had been previously discovered between age groups, with a range of 77% use in patients less than 30 years old to 16% use in those greater than 70 years old.[7] This trend of decreased internet use with increased age was confirmed to be statistically significant in our study, where fewer patients aged 40–59 and 60 or older were found independently to have accessed the internet within the past year than patients who were less than 40 years old.

In the setting of an orthopaedic outpatient population, research has not established patient race as a predictor of internet access. The disparity in internet use amongst particular ethnic groups in the US had been characterized in 2011, which found that 77% of Caucasians, 66% of African Americans, and 62% of Latinos go online.[3] In comparison with the general US population, the results from our study found that the percent of orthopaedic outpatients who used the internet within the past year was lower in each ethnic group, with 63% of Caucasians, 49% of African Americans, and 50% of Latinos reporting use. As depicted previously, the annual household incomes in our patient population were substantially lower than the incomes representative of US citizens in general, which conceivably had a critical impact on the lower percentage of orthopaedic outpatients in each ethnic group who were found to have used the internet in our study. Despite the smaller percent of patients with internet access in our study, their disproportionately low household incomes was an improbable explanation for the inability of our study to identify a statistically significant variation in internet access contingent on patient race. With the significant relationship between internet access and income distributions that was demonstrated by our study, which illustrated an increase in internet access as income level increased, race would have compounded rather than eliminated any deviations in internet use because of the lower income levels that are present amongst ethnic minorities in the US. Alternatively, race as predictor of internet use most plausibly proved unattainable because of the demographic underrepresentation of Caucasians and the extraordinary predominance of African Americans in our survey populous at orthopaedic clinics in Philadelphia. Patients participating in our survey consisted of 24% Caucasians (95% CI: 17–34%), 52% African Americans (95% CI: 42–61%), and 24% Hispanics (95% CI: 17–34%), while a 2010 overview of race in the US found a distribution of 72.4% Caucasians, 12.6% African Americans, and 16.3% Hispanics.[21] Increasing the number of Caucasian patients participating in our survey would provide additional data on use of the internet in this ethnic group, allowing for a more representative comparison to African American and Hispanic patients, and thus enhancing the capability of our study to define race as a statistically significant determinant of patient internet use in the urban orthopaedic setting.

Survey participants who reported that a mobile phone was one of the primary ways they accessed the internet were comprised of 74% non-white (Latino or African American) and 26% Caucasian patients, as compared to 38% and 17% respectively, which were found amongst the 25% of all smartphone owners in the US who mostly went online using their cell phone.[16] Our study showed that of patients who used their smartphone as a primary way to access the internet, 48% were high school graduates, 35% attended some college, and 17% had a college degree. In comparison to smartphone users in the US, those found to primarily use their cell phone to go online consisted of 33% high school graduates, 27% individuals who attended some college, and 13% college graduates.[16] Of the patients in our study who primarily used their smartphones to access the internet, 57% had an annual household income less than $35,000, 26% made $35,000 to $50,000, and 17% earned more than $50,000. This was similar to the result from a 2011 US population of smartphone owners, 40% of whom earned less than $30,000 annually, while 29% had income of $30,000 to $50,000, and 17% made greater than $50,000.[16] These similar findings show that the patients on the other side of the "digital divide" identify mobile phones as their primary means of accessing the internet more frequently than other groups, which suggests that the widespread availability of smartphones is most likely another factor underlying the greater amount of African Americans who were found in our study to have access to the internet. Although this suggests some narrowing in the "digital divide" amongst African Americans, a more definite evaluation should be performed to better understand the extent to which increased use of mobile phones, as a primary source for internet access, has influenced this divide in orthopaedic patients of lower income.

In a 2011 survey on health topics, Fox established that of participants who accessed the internet, 63% of Caucasians, 47% of African American, and 45% of Latinos used the internet to look for health information.[3] Similarities were found in our orthopaedic outpatient population, where Latinos (33%) used the internet to research a personal health condition less often than Caucasians (67%) and African

Americans (77%), of which both differences from the Latino race were statistically significant in each comparison independently. Previously, it had been established that there were deficiencies in health topics on the internet that were important for patients, a finding that was particularly striking across Spanish-language sites, where more than half of the condition-related topics were not addressed.[2] Spanish was the primary language spoken by 50% of the Latino patients in our study, while none of the Caucasians and only one African American identified Spanish as their primary language. Although variation in linguistic characteristics did not contribute to a disparity in internet access in our population of orthopaedic outpatients as there was no significant variation between ethnic groups, the language barrier found to be unique to Latino patients in our study was the principle component underlying the propensity for Latinos to have used the internet less than other races to learn about a personal health condition. As opposed to these findings in Latino patients, the percent of African Americans who reported that they had used the internet to look for information about a personal health condition (77%) was unexpectedly high, and controversially surpassed utilization of the internet by Caucasians for this same purpose, a result which had never been found in studies of internet use for healthcare purposes in the US population. In medical patient populations, however, including in the orthopaedic outpatient setting, the influence that ethnicity has on internet use for personal medical education remains undetermined. Our survey of orthopaedic outpatients exemplified that Latino patients search the internet about personal health conditions less than Caucasians and African American patients, while in this urban setting, the use of the internet to learn about a personal health condition amongst African American patients was considerably more than has been reported in the general US population.

Despite providing useful insight into the internet access and characteristic of its use in the orthopaedic outpatient population, our study had a few shortcomings that may have hindered our ability to detect some statistically significant findings in this urban setting. Although the 100 patients who responded to the survey provided enough data to evaluate certain aspects of internet use in our study population, increasing the number of surveys administered, with the primary goals of increasing the size of the Caucasian and Latino groups while providing a greater subpopulation of patients who had access to the internet, would provide sufficient data to evaluate more of the subsequent questions that characterized use of the internet. In evaluating the design of the questionnaire, a shorter survey would have provided for a larger number of patients who chose to answer questions towards the end of the survey, which evaluated patient opinions and experiences based on a scale from strongly agree to strongly disagree. An additional oversight in the structure of the survey was the unexpected ability of patients to select multiple answers when describing their education level and type of health insurance, as this prevented any statistically significant evaluation based on type of health insurance and forced us to analyze results based on education by the highest level of education reported. Finally, in our assessment of smartphone use as a primary source for patient internet access, asking patients about their ownership of a smartphone would have enabled us to determine if owning a phone with online capacities had an influence on internet use based on the race of the patient and on their annual household income. Including this question would similarly have allowed us to more directly compare our patient population to the 2011 US population, which determined the percent of smartphone owners who used this mobile device as their primary means of accessing the internet based on ethnicity, income, and education level. This was opposed to our study, which could only determine the percent of patients reporting their mobile phone as a primary way of obtaining internet access who were of a certain ethnic group or in the various categories of annual household income.

Over the next few decades, the healthcare system in the US will continue to evolve with the more extensive integration of the internet into the field of medicine. While most patients in the US already have access to the internet, their use of online resources for obtaining information about their general health and personal medical conditions continues to progress. Within the orthopaedics community, trends in outpatient access to the internet and in the characteristics of patient internet use had been shown to be predicted by age, income, education level, and furthermore, now additionally by ethnicity. In the future, ethnicity and these other patient demographics should be considered when orthopaedic decisions are made, which may involve or be influenced by a patient's use of the internet, especially in an urban setting that consists of significant minority populations and is characterized by prevalent financial and educational inequalities. Efficiently and effectively improving patient use of the internet to obtain medical information will benefit both the doctor and the patient by enhancing patient education, while also strengthening the doctor-patient relationship and ultimately enabling the doctor to provide a higher quality of patient care.

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Medical Student Research Project

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The Shoe-Surface Interface as a Profile Component Responsible for Knee Injuries in American Football: A Systematic Analysis

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Introduction

Since the late 1940s, there has been concern about the increasing incidence of injuries in competitive sports, particularly the prevalence of lower limb injuries in American football players.[1] Hanley first identified cleat fixation as a potential risk factor of lower limb injuries.[2] Shortly thereafter, in 1969 Rowe et al.[3] and in 1971 Torg et al.[1] described the association between cleat characteristics and knee and ankle injuries in high school football players. Several subsequent studies identified turf characteristics and conditions as additional risk factors contributing to injuries.[4, 5] These early studies and findings were very influential in beginning an important area of research as well as helping to form guidelines for equipment use in organized sports.

Since that time, many studies have looked at the shoe, the surface or both in regards to athletic injuries. While study designs have varied and findings have been inconsistent, the importance of this topic grows with the popularity of football from youth to professional levels. The incidence of ankle, foot, and knee injuries in high school players was recently reported to account for 37.6% of all football injuries. At the NCAA football level, it was found to be 36.9% of all injuries.[6] An additionally interesting and important viewpoint is one of economics. The healthcare cost of treating these injuries has been estimated at many millions annually.[7] Furthermore, as Levy first pointed out, the economics of equipment used (in his case, field turf) is another important consideration.[8] Combining this information with such a large prevalence of injury displays the importance for risk factor identification and injury prevention through guideline formation, i.e. rules and regulations regarding both playing issues, environment, and equipment.

As the times changed, so has the equipment manufactured for athletic use. Updated materials and designs were used for cleats. Newer generations and engineering techniques have been applied to artificial turf.[8] The literature has also changed in order to evaluate the most current equipment being used at the shoe-surface interface. This has made an issue of interpreting seemingly outdated studies and their application for current recommendations. A recent publication has briefly highlighted a few historical points and findings and has called for more epidemiologic studies to investigate this area.[9] Our goal is to more completely inspect the history of the literature from its inception in order to shed light on the current state of the shoe-surface interface in American football injuries.

Methods

Pertinent articles were found using the NCBI's PubMed database and a keyword search including: "cleat," "shoe-surface interface," "football injuries," and "artificial turf." From the results, papers were excluded if they focused on information from European football rather than American football or if the injury topic did not focus on the lower extremity.

After reviewing these articles, levels of evidence were assigned to each publication and included in Table 1. Articles were reviewed for historical contribution to the research subject and relevance to current shoe-surface interface technology. The pool of literature was analyzed for trends and errors that reoccurred throughout the last 40 years.

Results

The database search described above resulted in 32 publications covering the time period from 1969 to May 2012.

As stated previously, in 1969 Hanely and Rowe identified that cleat fixation was a risk factor for injury.[2, 3] Further investigating this risk factor, Torg in 1971 reported on an investigational field study using Philadelphia Public and Catholic high school football league players that shoe designs that decreased foot fixation, the soccer-style shoe, was able to decrease injury rates.[1] Torg's study proposed a recommendation for shoe sole specifications that ultimate changed the equipment guidelines of both the National Federation of High Schools Associations and the National Collegiate Athletic Association. The following year, it was identified that surface characteristic were an additional potential risk factor and that increasingly popular artificial turf had an increased rate of injury compared to natural grass. Further

Table 1. Bibliography Levels of Evidence

Publication	Level of Evidence	Publication	Level of Evidence
Adkison et al.[10]	4	Livesay et al.[11]	2
Andreasson et al.[12]	2	Meyers et al.[7]	2
Bonstingl et al.[13]	2	Meyers et al.[14]	3
Bradley et al.[15]	2	Mueller et al.[5]	3
Bramwell et al.[4]	4	Orchard et al.[16]	3
Cameron et al.[17]	5	Powell et al.[18]	3
Cawley et al.[19]	-	Reider[9]	5
Dick et al.[20]	3	Rowe[3]	3
Dragoo et al.[21]	2	Shankar[6]	3
Ford et al.[22]	4	Skovron[23]	4
Garrick et al.[24]	3	Stanitski[25]	4
Hanley et al.[2]	5	Torg et al.[1]	1
Heidt et al.[26]	2	Torg et al.[27]	1
Keene et al.[28]	4	Torg et al.[29]	3
Lambson et al.[30]	2	Villwock et al.[31]	2
Levy et al.[8]	2	Williams et al.[32]	2

studies confirmed foot fixation as a risk factor and that the soccer shoe decreased injury rates compared to the traditional football cleat.[4, 5, 17]

An early work by Cameron and Davis on the swivel shoe aimed at reducing fixation was more influential in descriptively stating the mechanisms of several different lower limb football injuries.[17]

An interesting and new perspective was introduced by Stanitski in 1974 when he demonstrated that while artificial turf has a higher coefficient of friction, it provided increased player speed. From an injury standpoint, this was potentially a problem in that he proposed that "synthetic playing surfaces changed the complexion of the game by increasing player speed . . . may set the stage for increased collision forces between players with resultant increase in the severity of injuries."[25]

Adkison et al. subsequently demonstrated that not all artificial surfaces could be classified together. It was shown that AstroTurf had a greater injury rate than grass, but a different artificial surface, Tartan Turf, actually had a lower injury rate in a high school football study.[10] Several years later in a different study, Kennen et al. also found that Tartan Turf had a decreased numbers of injuries when compared to other surfaces, although interpretation of the results is possibly limited by study design.[28]

In a novel study in 1974, Torg designed an apparatus that could be used in the laboratory to model the shoe-surface interface with rotational motion. He defined the release coefficient (Force/Weight) and applied this value for guidelines of shoe and surface combinations and their safety factor. On the basis of study, it was concluded that the molded sole soccer type shoe with 15 cleats with a maximum cleat length of ½ inch ½ length and a minimum cleat diameter of ½ inch as being safe on all playing surfaces, both grass and artificial. He further concluded that shoes with this sole configuration were safe on all surfaces, except those constructed with rubber soles, were not safe on all synthetic surfaces.[27] His apparatus was the first of its kind and the model for many subsequent studies.[11, 12, 26, 31] The following year, Bonstingl et al., using a different laboratory apparatus, demonstrated that foot stance developed 70% more torque than did toe stance and that synthetic turf developed more torque than did natural grass.[13]

Supporting these shoe-surface observations, Andreasson et al. further demonstrated in 1986 that not only the design but also the material of the shoe sole was a variable that affected the shoe-surface interface. A laboratory study concluded that lower torque was developed in polypropylene-like soles as compared to polyurethane and rubber soles.[12] Much later, a different publication would speculate about the material used in the shoes upper and how the pliability might affect potential injuries, especially in the ankle.[31]

In 1990, Levy performed a literature review to cover the development and characteristics of artificial playing surfaces on the American football player. It was stated that several benefits of artificial surfaces include lower maintenance, resulting in lower costs, and increased playing time availability. While much of the research showed increased injuries on artificial turf, he conclude that "it seems likely that manipulation of field characteristics are not only possible but essential, if player safety is to be maximized."[8]

In 1992, Powell showed that AstroTurf was implicated in higher rates of ACL sprains and that certain positions (running backs and linemen) under specific circumstance (rushing and passing plays respectively) were more likely to sustain knee injuries.[18] Torg again broadened the knowledge of the subject by reporting the effect of temperature on the shoe-surface interface. He concluded that more pliable cleats had greater release coefficients and that this was directly related to increasing temperatures. He specifically stated that "soft rubber sole shoes on warm AstroTurf create a risk factor."[29] Further studying the design of the football cleat, in a 1996 study, Lambson et al. showed that designs producing higher torsional friction, those with long peripheral cleats, were related with increased ACL injury. It was also reaffirmed that running backs, linemen, and linebackers had higher rates of injury.[30] In another study that year, the concept of spatting, wrapping the cleat and ankle with tape, affects the characteristics of the shoe-surface interface.[26]

In a 2003 study on how weather conditions affect NFL injuries, it was shown that grass produced less ankle sprains than did AstroTurf and less ACL injuries occurred on cold days in open stadiums.[16]

While one study showed that the majority of injuries occurred during non-contact situations in the NFL,[30] two others identified that contact injuries were more frequent in the NCAA.[20, 21]

With the advent of newer models of artificial turf, more recent studies have demonstrated that FieldTurf may actually be safer than grass in that there were more knee injuries and greater time loss injuries on grass in high school football.[14] In addition, there was a decreased incidence of ligament tears on FieldTurf and a higher incidence of ankle

injuries on grass in the NCAA.[7] Although the latest epidemiologic study has stated that there is an increased incidence of ACL injury on artificial turf, especially the newer generations that include granular infill,[21] it should also be noted that the validity of the former study has been called into question because of the source of funding.

Discussion

The purpose of this paper is to present a systematic review of the history of the shoe-surface interface and its role in lower limb injuries in American football. More specifically, it is intended as a response to a recent opinion article by Reider that we believe to have been incomplete on several issues and misguided regarding its conclusions.[9]

Of the 32 articles reviewed, two met the qualification of level 1 level of evidence as a "high-quality prospective study with testing of previously developed diagnostic criteria on consecutive patients." We refer to the 1971 report that on the basis of a three-year prospective clinical study involving 34 high school football teams on the effect of shoe type and cleat length on the incidence and severity of knee injuries investigated within the confines the Philadelphia Public and Catholic Football Leagues, a marked decrease in both the incidence and severity of knee injuries was effected by changing from the conventional shoe with seven ¾-inch cleats to a shoe with a molded polyurethane sole with 14 ⅜-inch cleats.[1] The subsequent laboratory study using an assay device to determine the association of the shoe-surface interface release coefficient to the risk for football knee injuries was published in 1974.[27] Release coefficients, an expression of static friction, were determined for 108 shoe-surface interface combinations. By correlating these values with the results of the Philadelphia High School Study, safety characteristics were described for each shoe-surface combination. The laboratory determinations indicated that the release coefficients varied with the number, length, and diameter of the cleats as well as the nature, natural or artificial, and condition, wet or dry, of the surface. The study concluded that the conventional seven-posted football shoe with seven ¾-inch cleats was not safe on grass. On the basis of this report, both the National Collegiate Athletic Association and the National Federation of High School Associations outlawed these cleats in favor those of ½ inch in length. And this regulation persists today. It was also determined that the molded sole soccer shoe with 15 cleats was safe on all surfaces. Subsequent studies, however, demonstrated that because of the frictional quality of natural soft rubber soles, this material was probably not safe on synthetic surfaces.

An analysis of the above articles reveals that they are limited to what may be described as one leg of a three-legged stool. That is, the possible mechanisms of injury have not been integrated with the shoe-surface interface aspects of the problem and, except for two reports, environmental considerations were not included.[16, 29] With regards to the mechanism of injury issue, foot fixation is clearly associated with rotatory stresses resulting in both knee and ankle joint injuries. As well, injury resulting from exogenous forces such as a valgus strain combined with foot fixation is well recognized. Of note, however, recent understanding of non-contact anterior cruciate ligament injury suggest an axial loading force is the primary mechanism and is probably independent of shoe-surface interface foot fixation.[32] As noted, ambient temperature has been observed to have a direct effect on both the shoe-surface interface release coefficient and the anterior cruciate ligament injury rates.[18, 29]

Most authors agree that the football-induced knee injury problem is complex and multifaceted. We believe that the shoe-surface issue was basically resolved in 1971. That is, maximum cleat length of ½ inch on all surfaces and non-rubber synthetic sole shoes on artificial surfaces. However, knee injuries continue to occur and we believe a prospective attempt to collect data to develop an injury predisposition profile consisting of all possible predisposing factors: shoes, surfaces, injury mechanisms, environmental, and player demographics is indicated.

Conclusion

The shoe-surface variables are important but not the only factors responsible for the occurrence or prevention of athletic-induced knee injuries.

The limitation of football shoe cleat length to ½ inch on all surfaces, as mandated by both the NFHSA and the NCAA in 1974, has withstood the test of time.

The initial reports from the early 1970s recommending multicleated soccer type shoes with polyurethane/polypropylene soles for use on synthetic surfaces has also withstood the test of time.

It is recommend that there be data collection to develop an injury predisposition profile consisting of all possible factors: shoes, surfaces, injury mechanisms, environmental, and player demographics.

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Medical Student Research Project

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Tibial Plateau Fracture Outcomes Following Treatment with Plexur M Bone Graft: A Retrospective Case Review

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Abstract

Objective: To investigate the effectiveness of Plexur M (Medtronic, Minneapolis, MN) bone graft substitute in filling subchondral depression defects of the fractured tibial plateau by comparing its subsidence and complication rates to allograft and calcium phosphate substitutes.

Design: Retrospective chart and radiographic review

Setting: Level 1 regional trauma center

Patients and Methods: One-hundred-twenty-six patients with tibial plateau fractures treated with open reduction internal fixation and bone grafting between January 1st, 2005 and January 31st, 2012 were identified. Eighty-three patients were lost to follow-up and excluded. The remaining 43 patients had at least six months of follow-up with available radiographs, thus were included as study subjects. Thirteen patients received Plexur M bone graft, 14 received calcium phosphate bone grafts, and 17 received allograft. Follow-up digital radiographs were analyzed and subsidence of the articular surface at the fracture site was determined using electronic calipers. The primary outcome measure was subsidence. Secondary outcome measures included infection and reoperation.

Results: Individual comparisons among the three groups revealed that fractures treated with Plexur M had a 14% incidence of subsidence (2/14) compared to a 24% incidence (4/17) in the allograft group and a 15% incidence (2/13) in the calcium phosphate group. The observed differences in rates were not significantly different. Other complications, such as infection and reoperation, did occur but there were no statistically significant differences amongst the groups.

Conclusions: Plexur M is a viable alternative for the treatment of bone voids as a result of tibial plateau fractures compared to cancellous allograft and calcium phosphate.

Introduction

Displaced tibial plateau fractures, particularly those leading to joint instability, are frequently treated surgically, often with open reduction and internal fixation.[1] In the case of depressed fractures, bone graft material (in combination with open reduction and internal fixation (ORIF)) is commonly placed in the depression to fill any defects, provide structural support, and to serve as a scaffold for bone regeneration.[2] It is desirable that bone graft materials here provide immediate structural support, are easy to use by the surgeon intraoperatively, have minimal complications, and allow themselves to be replaced with bone over time.

Multiple bone graft options are available. Options include autografts as well as a variety of synthetic products. Several studies have shown that calcium phosphate graft substitutes are equal or superior to autograft based on clinical outcomes and strength testing, without complications of donor-site pain or infection.[3–6] Calcium phosphate is a commonly accepted bone substitute in the treatment of tibial plateau fractures in addition to allograft.[7, 8] Calcium sulfate materials can occasionally be difficult to use intraoperatively due to their material properties. Other bone grafts, such as calcium sulfate materials, have shown extremely rapid resorption and problems with sterile drainage from the surgical incisions.[9, 10]

Plexur M graft material (Medtronic, Minneapolis, MN) is a novel graft material consisting of milled cortical allograft bone fibers in a bioresorbable carrier (poly (DL Lactide-co-glycolide) and a calcium porogen). Most importantly, this particular graft material is moldable, and hardens intraoperatively, which we have found to be particularly useful for the surgeon trying to provide subchondral support for a depressed fracture. The objective of this study was to investigate clinical safety and efficacy of Plexur M in the treatment of depressed tibial plateau fractures.

Methods

After appropriate institutional review board approval was obtained, a retrospective review of patient charts was performed. Inclusion criteria consisted of patients admitted to our institution between January 1st, 2005 and January 31st, 2012 with tibial plateau fractures treated with ORIF and bone graft. Patients with less than six months of follow-up were excluded from the present study. Patients were divided

into three groups based upon the treatment used: Plexur M bone graft substitute (Medtronic, Minneapolis, MN), allograft, or calcium phosphate bone graft substitute. Calcium phosphate bone graft substitutes included: Vitoss (Orthovita, Malvern, PA), Hydroset (Stryker, Kalamazoo MI), and chronOS (Synthes, West Chester, PA).

Patient outcomes were determined by reviewing the hospital's electronic medical record system. Data collected via patient chart review included patient age, gender, date of surgery, date of follow-up, surgical fixation method, tobacco use status, diabetes status, compartment syndrome in the surgical leg requiring fasciotomy, as well as open or closed fracture status. X-ray review by two orthopedic surgeons was performed to determine the Schatzker fracture classification (Table 1).

Table 1. Schatzker Fracture Classification System[12]

Schatzker Fracture Classification	Description
Type I	Split or wedge fracture of the lateral tibial plateau, usually occurring in young patients with strong bone
Type II	Lateral split-depression fracture in which the medial aspect of the split is depressed
Type III	A centrally-located depression, usually resulting from lower-energy injuries
Type IV	Fracture of the medial tibial plateau
Type V	Bicondylar fracture of both the medial and lateral tibial plateau
Type VI	Tibial plateau fracture with an associated proximal shaft tibia fracture

Post-surgical subsidence and complications were assessed as primary and secondary outcomes of this study, respectively. Complications were defined as negative outcomes resulting in surgical intervention that could potentially be attributed to the bone graft or bone graft substitute. Included in this outcome measure were infections, which were defined as any peri- or intra-articular infection that, again, required operative intervention (superficial wound infection, septic arthritis, osteomyelitis, etc.). Individual complications are detailed by graft type and Schatzker class in Table 3.

Experimental methods to assess fixation were modeled after previous studies of subsidence in depressed tibial plateau fractures.[7, 13, 14] Subsidence was measured by two separate reviewers (radiologist and orthopedic surgeon) without knowledge of the treatment group, using radiographs viewed at a minimum magnification of 200%. Measurements were taken from the intact articular surface to the surface of the depressed fragment (Figure 2). Repeated measurements were averaged. Measurements were taken immediately postoperatively, and again at a minimum of six months. The difference between the measurement at the time of surgery and at six months was calculated and used to determine subsidence. A distance of 2 mm or greater between the surfaces was classified as positive subsidence.[7]

Radiographs were viewed using a Picture Archive and Communication System (PACS). Radiographs taken at the time of surgery were measured directly using electronic calipers. In some follow-up radiographs where the images were digitized, a known measurement (usually the distance between the most lateral and medial edges of the femoral condyles) was used for calibration in order to measure the subsidence. Figures 1 and 2 are examples of negative and positive evidence of subsidence, respectively. These images were provided to the independent reviewers for reference. Figure 2 also provides landmarks used for radiographic determination of subsidence.

Statistical analyses were performed using univariate logistic regression for each potential factor related to outcomes (complications, infection, subsidence, etc.). Follow-up pairwise comparisons were made among the three treatment groups. A Bonferroni adjustment was made to p-values to account for experiment-wise type 1 error. Individual rates for complication and subsidence were compared using Fisher's exact test.

Results

Retrospective review of tibial plateau fractures at our institution treated with ORIF from January 1st, 2005 to January 31st, 2012 resulted in a total of 273 patients, 43 of whom were included in this study. Of the original 273 patients, 125 underwent ORIF with bone graft or bone graft substitute and had bone graft material information available. After six months, 82 patients did not have radiographs in our PACS system, leaving 43 patients for analysis. They were categorized into three groups as follows: 13 patients received Plexur M bone graft substitute, 13 patients received calcium phosphate bone graft substitute, and 17 received allograft. Average subsidence and standard deviation of the three groups are summarized in Table 2.

Following logistic regression for an overall effect, pairwise group comparisons among the three treatment groups were performed. Fractures treated with Plexur M had a 14% incidence of subsidence (2/14) compared to a 24% incidence (4/17) in the allograft group and a 15% incidence (2/13) in the calcium phosphate group. The observed differences in rates were not significantly different.

Other complications, as previously defined, did occur but were not statistically significant between groups. These comparison were allograft versus calcium phosphate ($p = 0.56$), allograft versus Plexur M ($p = 0.88$), and calcium phosphate versus Plexur M ($p = 0.68$).

Potential confounding factors, including age, gender, smoking, diabetes, compartment syndrome and open fracture status were analyzed to see if there were any between-group differences that could be attributable to these underlying comorbidities. Age was not associated with a greater amount of subsidence ($p = 0.323$) or complications ($p = 0.512$). Gender was not found to impact subsidence (p =

Figure 1. Example of negative read for subsidence.

Figure 2. Example of positive read for subsidence. The right pane also illustrates the landmarks used for radiographic determination of subsidence.

0.805) or complications (p = 0.609). Between the allograft, calcium phosphate and Plexur M groups, the number of smokers was 10, four, and seven respectively and the number of diabetics was one, one, and one. Smoking was not found to impact complication (p = 0.907) or subsidence (p = 0.402). Neither compartment syndrome (p = 0.492) nor open fractures (p = 0.973) were found to correlate with complications rates.

Other complications leading to re-operation noted in the Plexur M group included two cases of arthrofibrosis, one case of osteomyelitis, and one case of aseptic knee pain (Table 3).

Discussion

Patients with depressed tibial plateau fractures treated with Plexur M were found to have a lower incidence of subsidence than patients treated with allograft and an equal rate to those treated with calcium phosphate bone graft substi-

tute. Patients treated with Plexur M were found to have a lower incidence of re-operation than patients treated with allograft but a higher rate than those treated with calcium phosphate (Table 2). Plexur M had the lowest infection rate (8%) of all the groups, though this was not statistically significant when pair-wise group comparisons were performed for overall complication rate, as noted in the results above. In general, the relatively high incidence of infection in this study was somewhat higher than expected. That said, the majority of patients who underwent ORIF of a tibial plateau fracture did not have sufficient radiographs available for six-month follow-up in our PACS system and were thus excluded from the study. Many of those patients had radiographs done elsewhere during follow-up due to insurance restrictions, or were not seen in follow-up long enough for meeting the six-month requirement. It could be speculated that whereas patients who did well early in their postoperative course did not continue to follow up, patients with infections required prolonged follow-up and multiple radiographs.

There were two cases of arthrofibrosis associated with the use of Plexur M bone graft substitute. While there is not enough data to support or refute the association of increased peri-articular scarring with the use of Plexur M bone graft, further studies are needed to elucidate the significance this finding.

Table 2. Number of Cases (Percentage) with Either Subsidence Greater than 2 mm or a Complication (as Defined in the Text) Divided by the Total Number of Cases in Each Group

	Subsidence	Complication	Infections
Allograft	4/17 (24%)	7/17 (41%)	6/17 (35%)
Calcium Phosphate	2/13 (15%)	4/13 (31%)	3/13 (23%)
Plexur M	2/13 (15%)	5/13 (38%)	1/13 (8%)

Infections requiring operative intervention are listed here as a subclass of overall complications. For rate of subsidence greater than 2 mm, allograft vs calcium phosphate, $p = 0.5860$; allograft vs Plexur M, $p = 0.5860$; calcium phosphate vs Plexur M, $p = 1.0000$.

Infection and subsidence rates in this study were compared with available literature for the use of allograft and calcium phosphate bone substitutes. Quoted infection rates for calcium phosphate and allograft from a recent meta-analysis are 3% and 9%, respectively.[15] In 2003, Simpsons and Keating reported loss of reduction in 61% of autograft patients and 23% of calcium phosphate patients with lateral tibial plateau fractures,[16] and in 2001 Keating, Hajducka, and Harper reported loss of reduction in 16% of patients treated with calcium phosphate bone graft substitute.[17]

The results of the current study suggest that Plexur M bone graft is a safe and viable alternative to allograft and calcium phosphate bone graft substitutes for treatment of bone voids as a result of tibial plateau fractures. It is not associated with a statistically significant higher incidence of subsidence or rate of other complications including infection or reoperation when compared to allograft and calcium phosphate.

The material properties of Plexur M are arguably preferable to calcium phosphate, synthetic graft substitutes and certain types of allograft because of its moldability, machinability, and set-time. It also avoids the complications of autografts such as donor-site pain or infection, as well as the high incidence sterile drainage that is reported with calcium sulfate grafts, thus making it a desirable material to use in the fixation of tibial plateau fractures.[9–11]

This study is not without its limitations. It is a retrospective chart and radiographic review with a large proportion of patients without sufficient radiographic follow-up in our PACS system for review. The minimum acceptable follow-up period of six months is also relatively short and inconsistent among the analyzed patients. However, follow-up time was not proven to impact subsidence or complication rate.

The patients in this study represent individuals with tibial plateau fractures treated with ORIF and bone grafting over a consecutive eight-year period. It is noted that most patients

Table 3. Summary of Complications and Associated Interventions by Graft and Fracture Type

Graft Type	Case No.	Schatzker Type	Complication; Surgical Procedure
Allograft	1	2	Abscess; debridement
	2	2	Flexion contracture, heterotopic ossification; osteotomy
	3	2	Septic arthritis; debridement, implant removal
	4	2	Wound infection, sinus tract; multiple debridements, implant removal, local flap, skin graft
	5	5	Wound infection; debridement, implant removal
	6	6	Wound infection; debridement, implant removal
	7	6	Wound infection; debridement, implant removal
Calcium phosphate bone graft substitute	1	2	Degenerative joint disease; total knee arthroplasty
	2	5	Persistent wound drainage; debridement
	3	6	Wound dehiscence, septic arthritis; incision and drainage, implant removal, local flap, skin graft
	4	6	Septic arthritis; incision and drainage, implant removal, skin graft
Plexur M bone graft substitute	1	2	Wound infection; implant removal
	2	5	Arthrofibrosis; manipulation, lysis of adhesions
	3	5	Arthrofibrosis; Judet qudricepsplasty
	4	6	Culture negative effusion, persistent knee pain; incision and drainage
	5	6	Osteomyelitis; debridement, implant removal

received allograft near the beginning of the study period, while Plexur M was used more often in the latter part of the study. Calcium phosphate substitutes were used with greatest frequency in the middle of the study period. This is an unintended consequence of the retrospective design of this study and purely reflects the choices made by the surgeon at the time the patients were treated. Plexur M was approved by the FDA in March of 2008 and was not used in any of the patients in this study until after that date.

Subsidence measurements were made using digital x-rays. Some error was noted due to slight variation in the angulation and rotation of the radiographs between immediate postop and follow-up x-rays. Only anterior-posterior images were used to record these measurements. In order to account for this variation and any error in calculating the pixel to millimeter conversion for radiograph reading of subsidence, subsidence measurements less that 2 mm were not considered, similar to previously reported studies.

Larger prospective studies with longer, more consistent follow-up are needed to reliably compare Plexur M with its alternatives and to further delineate the risk factors associated with its use.

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Medical Student Research Project

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Treatment of Articular Fractures with Continuous Passive Motion

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Key Points

• In animal studies, CPM has been shown to improve cartilage healing after injury compared with immobilization. Human studies have also shown the improved rate of hemarthrosis clearance with CPM compared with immobilization.

• Clinical studies of CPM have mostly come from the total knee replacement literature. Its use in joint replacement (which does not rely on cartilage repair), however, only partially translates the potential benefits of CPM.

• CPM has been used extensively in the postoperative care of articular fractures treated with ORIF, a natural extension of the early basic science studies' purported clinical use. It is felt to help improve cartilage repair, range of motion, and clearance of hemarthrosis. However, little attention has been paid specifically to CPM as a treatment modality.

• Better clinical studies of CPM as a treatment modality for articular fracture management are warranted to determine its potential benefits, and to more clearly specify parameters for its use in specific clinical scenarios.

Synopsis

This article presents a review of the basic science and current research that exists on the use of continuous passive motion therapy following surgery for an intraarticular fracture. This information will be useful for surgeons in the postoperative management of intra-articular fractures in determining the best course of treatment to reduce complications and facilitate quicker recovery.

Introduction

Primarily used to reduce joint stiffness following joint surgery or trauma, continuous passive motion (CPM) therapy works to counteract the pathological stages of joint stiffness: bleeding, edema, granulation tissue and fibrosis.[1] This post-operative therapy has been utilized for a variety of orthopedic surgeries including the management of total knee arthroplasty, fracture repair, rotator cuff repair, hand rehabilitation, and ACL reconstruction rehabilitation.[2–4] Salter pioneered the use of CPM in the 1980s after observing the therapy's ability to stimulate articular cartilage healing and prevent complications caused by immobilization post-injury in rabbit models[1, 5] (Figure 1). Further animal studies went on to investigate continuous passive motion therapy's role in reducing joint stiffness following intra-articular injury.[6]

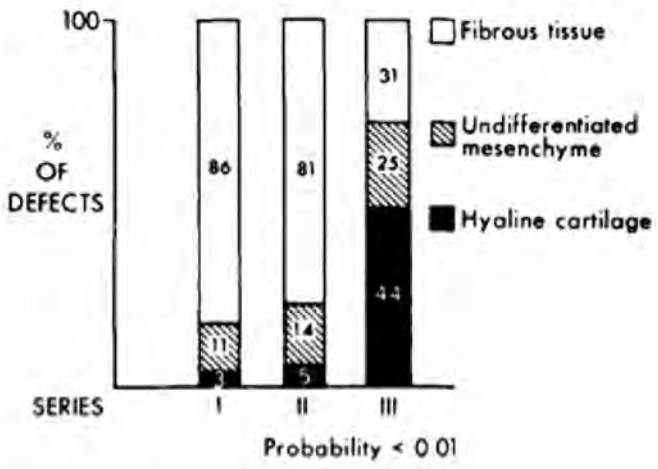

Figure 1. Improved cartilage repair seen with continuous passive motion from animal studies (from Salter et al.,[5] with permission from the publisher).

First index of healing: the nature of the reparative tissue at three weeks in the 36 defects in each of the three series in adult animals. The bars depict the percentages of the 36 defects in each series that exhibited predominantly hyaline cartilage, incompletely differentiated mesenchymal tissue, and fibrous tissue. The nature of the reparative tissue in the defects treated with continuous passive motion (Series III) is far superior to that after either immobilization (Series I) or intermittent active motion (Series II).

However, while studies conducted on animal models demonstrate a significant benefit in CPM use following injury, studies carried out in a clinical setting show more conflicting results.[6–9] The many variations in clinical CPM protocols could be partially to blame for this lack of agreement with no standard method of use dictating the number of degrees per day the machine should advance or the number of hours per day the treatment should last.[10] Despite this lack of conclusive evidence showing definitive benefits when used clinically, CPM therapy has become standard practice in many centers for post-operative treatment of many joint injuries. However, CPM therapy remains a highly-debated treatment with some recent studies highlighting the treatment's disadvantages such as the need for the patient to stay in bed, the increased costs of maintaining and operating the units, and the extra technical support patients require from their nurses.[11] With CPM's potential to facilitate faster recovery, shorten patients' lengths of stay, and as a result, reduce costs,

many hospitals could benefit from a definitive verdict on the effectiveness of CPM therapy.

Much of the clinical research focuses on the efficacy of this treatment in increasing range of motion and decreasing hospitalization time and post-operative complications following total knee arthroplasty when compared to a regimen focused on physical therapy alone.[12] However, very little research exists on the use of CPM for the management of articular fractures. Many articular fractures, such as tibial plateau fractures, can develop stiffness as a sequelae.[13] Recovery from this fracture, as an example, is also often further complicated by significant soft tissue injury and can involve collateral ligaments and the anterior and posterior cruciate ligaments.[14] In addition, the significant amount of bleeding associated with the soft tissue injury and fracture of the proximal tibial metaphysis can lead to compartment syndrome, and post-operative complications such as deep vein thrombosis can develop.[14] Given the nature of these possible complications and the proposed benefits of CPM which include the potential to decrease hemathrosis, and decreasing the incidence of deep vein thrombosis in trauma patients, CPM therapy has the potential to offer many advantages post-operatively.[15] However, our understanding of the efficacy of CPM in the management of articular fractures is not well understood, as few studies have specifically examined CPM in this setting, although its use in total knee arthroplasty patients has been examined.

In this paper, we review the rationale and basic science evidence for CPM in articular injuries and review the clinical evidence in the postoperative treatment of intra-articular fractures.

Continuous Passive Motion Therapy: Investigating Potential Benefits

The historical progression to the development of CPM started off with early research done through the 1950s, 60s and 70s which demonstrated the effects of immobilization compared to joint motion on articular cartilage. These early studies provided evidence of the harmful effects of immobilization which caused deterioration and articular cartilage loss in animal models. Fibrocartilage replaced the articular cartilage, and adhesions developed after immobilization, and after 30 days of immobilization, the cartilage damage could not be reversed like it could be with changes seen in soft tissue. However, this damage could be prevented if immobilization was limited and early exercise was emphasized.[16]

Salter pioneered the use of continuous passive motion through his early work starting in the 1970s. He and his colleagues conducted numerous studies on rabbit models and specifically looked at CPM therapy in improving the outcomes in synovial joint injuries. Salter compared CPM therapy to immobilization in his rabbit models, starting CPM immediately after surgery and continuing non-stop for one to four weeks. He found that the new therapy stimulated healing of the articular cartilage and led to faster and better healing when compared to both immobilization and limited active motion. In looking specifically at intra-articular fractures, CPM therapy stimulated articular cartilage growth and, therefore, was protective against degenerative arthritis development and resulted in better surgical wound healing.[1] In his 1984 publication, he summarized his findings as well as presented an early report on the clinical applications of continuous passive motion. In this retrospective study, he observed the effects of continuous passive motion for various joint injuries of the hip, knee, ankle, elbow and finger. Salter's early research summarized in this case study support the use of CPM therapy in preventing joint stiffness and facilitating healing, specifically for articular cartilage. Early success with rabbit models in the treatment of full-thickness articular cartilage defects, intra-articular fractures, acute septic arthritis, MCL reconstruction, and lacerations of tendons encouraged the use of CPM therapy in clinical applications. The nine cases Salter reviewed utilized CPM therapy for a variety of injuries (two intraarticular femur fractures, a patellar dislocation, two elbow fractures, one acetabular fracture, one intraarticular finger fracture, one hip infection, and one case of arthrofibrosis). This is clearly a very heterogenous group of cases to comprise this study. The protocol for CPM therapy followed by and recommended by these case studies indicates immediate post-operative use, starting in recovery and continuing without prolonged interruption for one week at one cycle per 45 seconds. Success in the clinical setting mimicked the early experimental success with patients treated with the CPM therapy reporting that they tolerated the treatment well and maintained the increased range of motion achieved through their respective surgical procedures. In addition, the case studies showed no CPM-related complications, periods of prolonged hospitalization or increase in patient pain or discomfort.[17]

Basic Science Evidence

Tendon Strength: Early reports of success with CPM therapy motivated further studies and its benefits on animal models. Loitz et al. used rabbit models to investigate the effect of continuous passive motion versus immobilization on the mechanical properties of tendons deprived of normal weight-bearing stimulation.[18] This design attempted to mimic the state of tendons following an injury, such as a fracture, which prohibited normal weight bearing. In this experiment, the 26 rabbit models were divided into two groups: an eight-member control group received no treatment and an experimental group of 18 rabbits received CPM to one ankle and immobilization for three weeks to the other after receiving an articular injury to both ankles without injury to surrounding tendons. The researchers then tested the collagen composition of the tendons and the mechanical properties. The thickness of the dissected tendons was measured with a digital micrometer and the mechanical strength by a servocontrolled electromechanical materials testing system. In addition, samples of the tendons were analyzed

for hydroxyproline content. While the cross-sectional area of control and experimental tendons were similar, averaging 0.9 $mm^2 \pm 0.2$ mm^2, the linear load for the immobilized tendons was found to be 16% less than the control tendons. The value for the CPM treated tendons was similar to that of the control tendons. In addition, the study found a significant difference in the strength of the control and immobilized tendons, with control tendons 20% stronger than immobilized and 16% stronger than CPM treated tendons. Looking at tensile strength, they found the control and CPM tendons to be similar with immobilized tendons showing 25% less strength than both. The composition of the tendons between the groups also differed, though not significantly; the hydroxyproline concentrations of the CPM tendons was 6% greater than both the control and immobilized tendons demonstrating the increased healing taking place. Overall, the study found the control tendons, as expected, were the strongest of the three while the tendons coming from the immobilized limbs the weakest. The tendons taken from injured joints and treated with CPM therapy fell in the middle and therefore demonstrated the role of CPM therapy in countering the harmful effects of short-term immobilization.

Joint Motion: Also comparing CPM therapy to immobilization in an animal model, Namba et al. focused on treating post-traumatic joint stiffness.[6] This experiment again utilized rabbit models. After sustaining intra-articular ankle injuries in two of their ankles, the 10 rabbits received the two different treatments: one ankle was treated with immobilization in a cast at 90 degrees flexion and the other with a CPM machine for three weeks at 24 hours a day. Evaluating joint stiffness specifically, Namba found that at three weeks, the immobilized joint was 2.6 times stiffer than pre-injury levels while the CPM treated joint showed no significant difference when compared to pre-injury levels. While CPM helped maintain joint function post-injury, no significant difference was found between the groups in terms of joint swelling.

Wound Healing: The effect of CPM therapy on wound healing is another important consideration in evaluating the treatment. Van Royen et al. compared the effects of CPM to cast immobilization in post-operative wound healing.[19] His histological and functional tests found that CPM treated wounds were significantly stronger and the histological structure of the collagen fibers showed better organization in the CPM treated wounds. In this experiment, van Royen used rabbits as his animal models and made skin incisions around the patella and into the knee joint. He then divided the rabbits into two groups: the immobilization group's knees were held at 80 degrees flexion for three weeks, while the CPM group received the therapy for the same duration of time. After three weeks of treatment, van Royen collected samples from the healing wound to observe the collagen organization and test the strength. Finding improvements in the strength and healing of the CPM treated wound, the study concluded that the added tension from the therapy improved the healing of the wounds.

Tissue Repair and Regeneration: Beyond being used to reduce joint stiffness and increasing tendon strength after injury, two studies done by O'Driscoll et al. and Kim et al. looked at CPM therapy's potential to stimulate neochondrogenesis and peripheral nerve repair.[20, 21] Using animal models, O'Driscoll found that a periosteum graft put into the knee joints of 30 rabbits showed evidence of articular cartilage growth after two weeks in the CPM-treated group when compared to the immobilized group. The CPM group had significantly more cartilage than the immobilization group: 59% of the graft consisting of cartilage in comparison to 8% respectively. Using animal models, Kim et al. found no statistically significant difference between the CPM group and the immobilization group in average nerve conduction and average fiber density following nerve transection. Therefore, as previous research demonstrating the benefits of CPM therapy suggest, CPM has the potential to stimulate cartilage growth, but does not appear to have any effect on nerve repair.

Frequency and Treatment Parameters: Basic Science and Clinical Evidence

As mentioned previously, CPM is used frequently by clinicians, but there are few guidelines for the timing of treatment, frequency, duration, and other treatment parameters. Studies done by Gebhard et al. and Shimizu further demonstrated the benefits of CPM therapy, and also set forth more specific parameters of use.[22, 23] Both studies used animal models to find the ideal number of hours per day needed to get the benefits of CPM therapy. Another study done by Takai et al. looked at the effect of the frequency of the CPM machine cycles on the healing of tendons.[24] His study indicated that the frequency might allow for a shorter duration of use with the same benefits.

Investigating duration of treatment, Gebhard et al. looked specifically at joint stiffness, muscle mass, bone density and regional swelling following intra-articular injury.[22] Again using rabbit models, 30 rabbits received an intra-articular injury by drilling a tibial pin into their ankle joints. The rabbits were then divided into five groups to receive four, eight, 12, 16 or 24 hours of CPM each day on one injured ankle and immobilization on the other ankle. When not undergoing CPM therapy, the rabbits were immobilized. After three weeks, the rabbits were evaluated. In looking at each of the parameters measured, Gebhard and colleagues found that only the rabbits treated with either 16 or 24 hours of CPM therapy saw any benefits in reducing joint stiffness. In fact, rabbits that received the shorter duration CPM therapy actually showed a worsening in mobility, with the CPM-treated limbs as much as four times stiffer than immobilized limbs. In terms of swelling, the 24-hour group was the only to show any benefit, though the decrease was not significant. All of the CPM groups increased in muscle mass being 13% greater than the immobilized limb. However, bone density went against the previous trend with longer CPM duration having more benefits, and an increase in bone density was observed

only in those treated with 12 hours or less of CPM therapy. Bone density data showed a statistically significant inverse relationship between duration and bone density: those treated with 12, eight and four hours of CPM per day had progressively more bone density than those with immobilization or 16 and 24 hours CPM per day. Through his experiments with animal models, Gebhard demonstrated the differing effects of CPM therapy on different tissue types and recommended that the therapy be employed for at least 16 hours per day to prevent stiffness, reduce swelling and increase muscle mass without having detrimental effects on bone density.

Shimizu et al. also focused on the dose-response relationship of continuous passive motion therapy.[23] The study again utilized rabbit models, and in both knees of all 34 rabbits, they exposed the knee joint and dislocated the patella as well as put holes in the articular bone of the femur. Post-operatively, the rabbit subjects were divided into groups based on the number of hours per day they would receive CPM treatment. All CPM machines were set at the same arc and cycle duration and the same immobilization cast, set at 90 degrees flexion, was utilized. Ten rabbits received CPM therapy 24 hours a day, six rabbits received CPM for eight hours a day and immobilization for the remaining time on one joint and CPM for two hours a day with immobilization on the other, seven rabbits remained immobilized for the full two weeks, nine rabbits were allowed normal cage activity for the full duration, and five rabbit knees received immobilization for one week followed by one week of 24-hour-a-day CPM therapy. After treatment, the rabbits were allowed normal cage activity for an additional five weeks before being evaluated. Shimizu and his colleagues examined mobility, histological features, and the extent of cartilage repair. While no significant difference was found in passive mobility, visual and histological analysis of the joints treated with CPM for 24 hours per day and for eight hours a day showed better repair and healing in comparison to the immobilized and cage activity groups. In addition, the CPM conducted after one week of immobilization did not overcome the initial harm caused by immobilization. The findings led the group to recommend that continuous passive motion therapy should be started as soon as possible and that the most favorable results would be achieved when CPM is carried out for 8–24 hours a day, though brief periods of immobilization left no ill effects.

Takai and co-authors suggested that the cycles per minute of the CPM machine might allow for shorter durations of use.[24] In his study, he used dogs as the animal model and following flexor tendon injury and repair, the dogs were divided into two treatment groups. One group received CPM therapy for five minutes per day at 12 cycles per minute while the second group got the same therapy for 60 minutes a day at one cycle per minute. These parameters worked out to the same number of cycles per day, but at different frequencies. After harvesting the tendons, the gliding function and strength of the tendons were evaluated at three weeks and six weeks. While the function of the tendons was the same for both groups, the tendon strength of the higher frequency group was significantly greater. Therefore, while duration of CPM therapy is an important variable in the effectiveness of the therapy, the frequency of cycles might have an even greater effect on outcome.

Another important parameter that, like the others discussed above, remains unstandardized is the number of days the patient must use the CPM machine in order to see any benefits. Several clinical studies have looked at this variable. One study determined that three days of CPM therapy was sufficient after looking at effects of the therapy on two groups of patients.[25] The first group experienced post-operative knee or elbow stiffness that existed for some time before therapy while the second group used CPM therapy immediately following the injury. After only three days of therapy, the first group saw significant improvements in range of motion which was maintained on follow-up while the second group regained their pre-injury range of motion with the reduced CPM therapy duration as well. Other studies looked at patients following total knee arthroplasty. In a study by Bennett et al., an early flexion CPM group started a group at a greater degree of flexion in recovery and continued the treatment for seven days comparing the outcome with a standard CPM group and a control with no CPM therapy.[26] Overall, the early flexion group showed significantly greater range of motion in early on, but the groups showed similar results after one year of follow-up. Similarly, other studies comparing the number of hours per day dedicated to CPM therapy found no significant difference in the range of motion of the total knee arthroplasty patients.[10, 27] Overall, the literature suggests that no consensus has been reached on the optimum number of hours per days and the number of days the continuous passive motion therapy should be administered.

Mechanisms of Action

While these previous studies illustrated the potential benefits of CPM therapy, O'Driscoll et al. investigated the mechanism behind the beneficial effects of continuous passive motion therapy.[7] O'Driscoll hypothesized that clearance of this blood from the joint with CPM can facilitate recovery and reduce stiffness. In his experiment using rabbit models, seven of the 16 received labeled erythrocyte injections into their knees and were scanned that day and subsequently on days one, two, three, four, and seven. Nine rabbits were injected with unlabeled blood as controls. After the injections, one knee was immobilized while the other underwent continuous passive motion therapy continuously for seven days. After seven days of treatment, the knee joints of the rabbits were dissected and examined. The results from the scans taken during the treatment showed that after 48 hours of CPM therapy, the knee synovial fluid was clear in comparison to the fluid taken from the immobilized joint which was bloody. Overall, the rate of clearance was twice as fast

in the CPM-treated joint than in the cast-immobilized joint with the clearance of 50% of the blood occurring in 2.2 days compared to 5.5 days respectively (Figure 2). In looking at the joint after the seven days, 7.1% of the original injected number of erythrocytes were found in the CPM-treated knee in comparison to the 13.2% found in the immobilized knee. The authors explained this difference by postulating that during the continuous passive motion treatment, the intra-articular pressure in the joint is raised and lowered creating a pumping effect that aids in clearance.

By measuring the intra-articular pressure of a human knee during CPM therapy in a separate study, Pedowitz and colleauges supported the hypothesis put forth by O'Driscoll.[28] In a study with 16 patients, the CPM machine was set at zero to 90 degrees of flexion with one cycle per 150 seconds. After taking pressure measurements at full extension and flexion for three complete cycles for 90 minutes, the researchers found that the pressure was the most at the extremes of joint flexion and extension. The minimum pressure occurred at 30 to 60 degrees of flexion (Figure 3). These cyclic pressure gradients both aid in fluid clearance and helped stimulate tissue healing, explaining the benefits seen with CPM therapy.

Clinical Evidence for CPM in Articular Fracture Management

Clinical use of CPM has been investigated, with relatively mixed results, in the total knee arthroplasty literature. But the full benefit of CPM would theoretically be seen with articular cartilage injury treatment, in accordance with the animal data discussed above. For many periarticular fractures, early motion is indeed emphasized to prevent "fracture disease," as popularized by the AO movement. But specific details about the clinical efficacy of CPM machines for management of particular articular fractures with regard to the optimal timing, duration, frequency, and motion parameters is not well studied. In this section, we will review the available clinical literature in an attempt to address this. However, although CPM is used frequently for these injuries, few studies actually specifically investigate CPM.

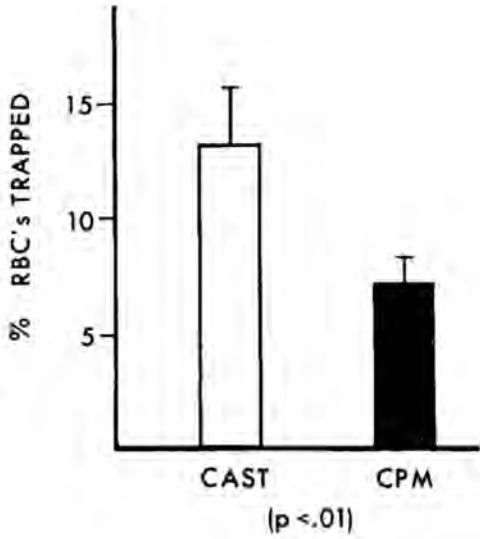

Figure 2. Clearance of hemarthrosis with CPM compared with cast immobilization of the knee (from O'Driscoll et al.,[7] with permission from the publisher).

The bars represent the percentages of injected ^{111}In-labelled erythrocytes that remained trapped in the synovium after seven days. Treatment by continuous passive motion decreased this trapping by approximately 50%. Values are expressed as mean ±1 standard error of the mean.

An Example of the Benefits of Early Motion: Tibial Plateau Fractures

Tibial plateau fractures represent a periarticular fracture group for which surgery is frequently done, and early motion is typically recommended. Gausewitz et al. reviewed the treatment of 122 acute tibial plateau fractures to determine the effects of early mobilization in rehabilitation. While the earlier studies demonstrated benefits for early motion, certain risks such as loss of fracture reduction, failure of internal fixation and compromised healing remained. Dividing patients into groups based on the amount of time they spent immobilized, Gausewitz and colleagues measured overall outcome by analyzing knee flexion, loss of fracture reduction, hospital length of stay and ligamentous laxity.[29] The review of patients and results revealed that patients treated without surgical intervention and immobilized for up to six weeks regained full range of motion. However, patients treated surgically with open reduction and internal fixation developed stiffness after only two weeks of immobilization. While the range of motion measurements were not statistically significant, after two to six weeks of immobilization, four of the 13 patients had flexion of less than 105 degrees and three had flexion contractures in comparison to the immediate motion group, which had only one flexion contracture and one patient with less than 105 degrees flexion. Despite the improvements in range of motion in the patients with shorter immobilization times, the patients' lengths of stay was found to be longer. The 23 patients with less than two weeks of immobilization stayed an average of 18.1 days in comparison to those with greater than two weeks of immobilization who stayed an average of 5.7 days. These values could be a slight misrepresentation of drawbacks to the treatment, however, since the longer stay of the patients with earlier mobilization was often due to the use of traction and a cast brace in comparison with patients who were simply discharged in a cast. The primary impact of the study was to highlight the benefits of early mobilization for surgically-treated fractures in recovering and maintaining range of motion.

Blokker et al. also related patient outcome to immobilization time in patients recovering from tibial plateau fractures.[30] In his review, he considered adequacy of reduction, immobilization time, fracture type, treatment method and overall result when evaluating patient outcome. However,

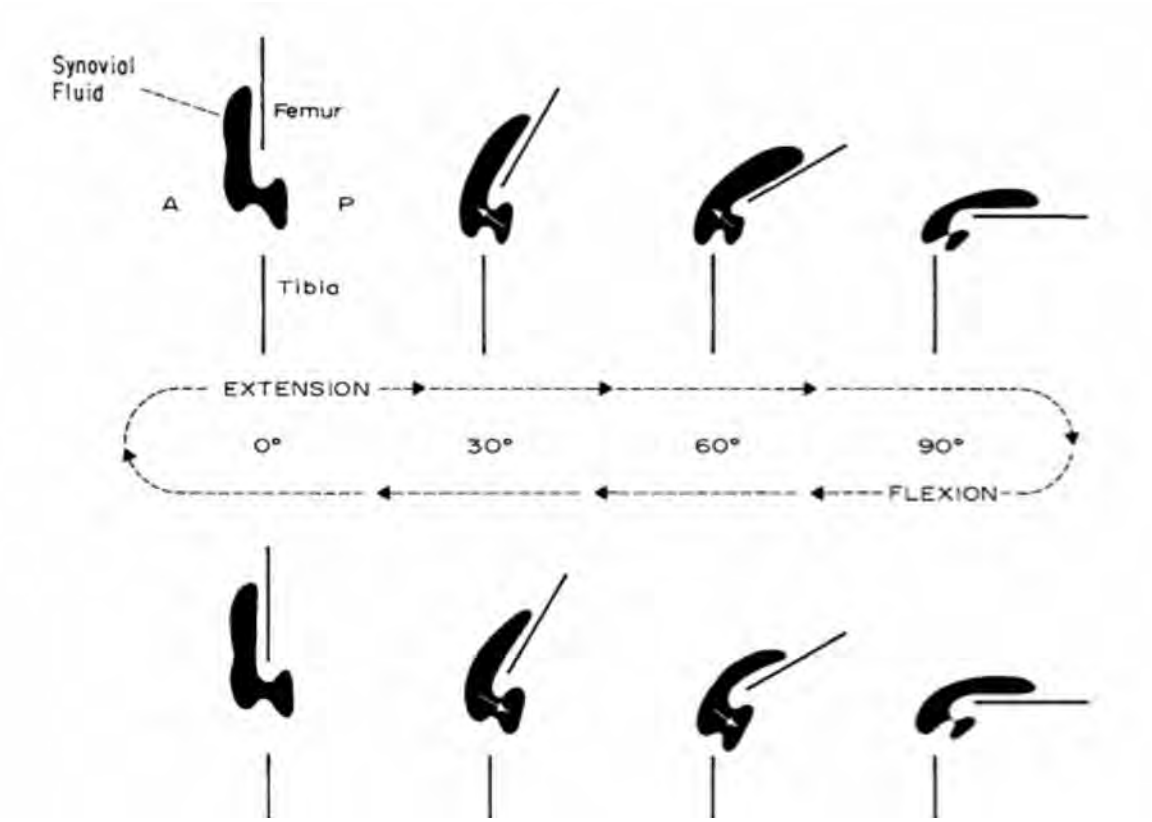

Figure 3. Intraarticular fluid flow during CPM, consistent with "physiologic compartmentation" of the human knee (from Pedowitz et al.,[28] with permission from publisher).

the results of his review could not support the earlier findings that demonstrated the strong relationship between early motion and better outcome in the patient. Patients were reported to have a satisfactory outcome if they achieved a range of motion of at least 90 degrees flexion, a lack of extension of less than 10 degrees and had returned to full activity with occasional mild pain or ache. 75% of the 60 patients evaluated reported a satisfactory result. He found no difference in outcome in patients who started knee movement in the first two weeks compared to those who started after. However, the authors also recognized that if motion was started by the first or second day of recovery rather than simply within the first two weeks, the results might have been more favorable for early motion. In addition, the assessment of satisfactory versus unsatisfactory result was done three years after the injury and no intermediate assessments were included. Therefore, the possibility existed that some more significant differences between the early mobilization group and the group immobilized for more than two weeks could have been observed.

In a similar study involving tibial plateau fractures, Lachiewicz et al. focused on cases treated surgically with open reduction and internal fixation.[31] This study reviewed the cases in order to determine the factors that influenced clinical and radiographic outcomes. The 43 fractures evaluated received several different post-operative treatments with 17 getting CPM therapy, 12 having a long-leg cast for six weeks because of ligament injuries, six in a knee immobilizer for six weeks, and the final 16 receiving instruction in range of motion exercises. However, with the focus of the study not being on post-operative treatments, the patients were not further divided up or analyzed based on these various treatments specifically. Overall, the authors found that 35 of the 43 had excellent results, with bicondylar fractures presenting the most difficulties. Patients who experienced this type of fracture were found to have an 18 degree decrease in range of motion in comparison to other patients. Interestingly, 10 of the 15 patients were in an immobilizer for more than three weeks. In addition, other patients treated post-operatively with an immobilizer for more than three weeks also experienced a decreased mean range of motion, measuring 14 degrees lower than those in an immobilizer for a shorter time period. This difference was found to be statistically significant. In summary, Lachiewicz demonstrates preliminary support for the use of early continuous passive motion in the treatment of tibial plateau fractures.

In a prospective study, Gaston et al. evaluated knee function during recovery of a fracture of the tibial plateau.[32] Fifty-one of the 63 patients were treated surgically with internal fixation while another five were treated with a combination of internal and external fixation and a final seven were treated non-operatively. Gaston and his colleagues tested joint movement and muscle function at three, six, and 12 months. At 12 months, only 14% had regained normal

quadriceps muscle strength while 30% had normal hamstring muscle strength. In addition, 21% suffered from residual flexion contractures. All the patients underwent standard physical therapy treatment for 12 weeks after surgery. The study outlined the slow recovery process after fractures of the tibial plateau. Whereas 82% of the patients had achieved 100 degrees of knee flexion, 21% still had extension deficits greater than five degrees, and this deficit was especially pronounced in patients over 40 years of age.[35] These deficits have an impact on daily life for patients with a minimum of 65 degrees of flexion needed for the swing phase of normal gait, a 90 degrees minimum needed to descend stairs and 105 degrees necessary for getting up from a chair.[12]

In a separate retrospective study, outcomes were measured differently by using HSS and Lysholm scores after tibial plateau fracture treatment along with CPM.[33] In this study, the knee was immediately placed in continuous passive motion, though the specifics of the CPM protocol were not included in the study. The study showed a significant decrease in activity due to knee complaints in the first two to three years following the injury; however, at three to six years following injury, these scores had increased to show good function and a return to pre-injury activity levels. This trend reversed itself after six years of follow-up though with patients again deteriorating due to an increase in arthritis. In contrast to the previous study which found age predicted a worse outcome, this study, which relied more on patient self-evaluation, found that the younger patients felt more impaired by the injury.

The results from the previous two studies above highlight the long recovery process that patients with tibial plateau fractures face, and the lack of consensus on post-operative treatment between the two further supports the need for more directed research.

Clinical Data for Articular Fractures and CPM

Several studies have recommended, without clear evidence, that CPM and early passive motion is important for recovery.[34, 35] We will hereby review clinical studies in which CPM was used for articular fractures as part of the treatment.

Proximal Tibia Fractures: Tibial eminence fractures are frequently treated with arthroscopic methods and fixation, with CPM used frequently postoperatively. Osti and co-authors reported 10 patients in which this was performed, and CPM was used postoperatively.[36] No specific data regarding timing, frequency, or other parameters for the CPM were provided. Patients achieved full extension, and flexion between 125 and 135 degrees. In a separate study, CPM was also used in 32 patients with tibial eminence fractures treated with arthroscopic fixation starting on postoperative day one.[37] Near full range of motion was achieved in all patients.

CPM therapy was used in some patients postoperatively treated with arthroscopic assisted tibial plateau fracture fixation as reported by Caspari et al.[38] Twenty-nine patients were treated in this case series, but there was no indication of how many patients were treated with CPM, or why it was chosen for those patients. In a similar study, arthroscopic-assisted tibial plateau fracture fixation was performed in nine cases with CPM used postoperatively.[39] Although no particular parameters were described, CPM was used for five days postoperatively and "clinical function was quite satisfactory" without more detail provided. Ohdera and co-authors did a comparison of arthroscopic with open reduction methods for treatment of tibial plateau fractures with CPM used for all patients postoperatively.[40] Parameters for the CPM were not described, nor was the exact timing ("several days after surgery"). In a similar study, 25 patients with tibial plateau fractures from skiing injuries treated with arthroscopic reduction techniques were managed with CPM postoperatively.[41] Again, no specific information was provided regarding the timing, frequency, or CPM parameters used other than it was used in the hospital postoperatively.

CPM therapy was also used postoperatively from 0–30 degrees in four patients with severe bicondylar tibial plateau fractures treated with combined anterior and posterior ORIF methods.[42] In another technique article, CPM was used immediately postoperatively and continued for two weeks at home, if indicated, for bicondylar tibial plateau fractures treated with ORIF.[43] Carlson described his experience with dual incision posterior ORIF of bicondylar tibial plateau fractures in eight patients who also had CPM postoperatively.[44] These patients were treated with CPM postoperatively in the hospital and continued until knee flexion was near 90 degrees. No other specific information regarding the CPM was provided in his report. There does not appear to be any particular problems with CPM use in the elderly as reported by Biyani and colleagues after ORIF of tibial plateau fractures.[45] In this particular study, CPM with cast bracing was compared with cast bracing alone postoperatively, with no significant difference in clinical outcomes. But there was no indication as to when CPM was chosen, and there were multiple fracture patterns with different surgeons and surgical approaches, making it difficult to draw conclusions regarding the efficacy of CPM for these patients.

Distal Femur Fractures: Similarly to treatment of tibial plateau fractures, surgeons have used CPM postoperatively after treatment of distal femur fractures. Shewring and Meggitt reported on 21 cases of distal femur fractures treated with the AO dynamic condylar screw and CPM started on the second postoperative day.[46] CPM was used twice a day for two weeks. Unicondylar femur fractures treated by ORIF in 16 cases in a separate study were also treated with CPM on the first postoperative day.[47] No other data regarding the specifics of the CPM treatment were provided. Other intraarticular femur fractures such as the "Hoffa fracture" have been treated with ORIF followed by CPM.[48]

Elbow Fractures: The elbow, unfortunately, is particularly prone to developing stiffness after trauma and surgery. CPM has, therefore, been looked to as a possible treatment

both after fracture fixation as well as surgery for release of arthrofibrosis. Frankle and co-authors reported 21 patients with elbow dislocations and radial head fractures treated by ORIF and benign neglect depending on the severity of the injury.[49] Early motion was performed in all patients, with CPM in only two patients. No additional data regarding the CPM was given in this study. Athwal et al. reported on 37 patients who underwent ORIF for AO/OTA type C distal humerus fractures, with some patients also having postoperative CPM treatment.[50] No specific data regarding timing, frequency, or CPM parameters were provided.

Other Articular Fractures: CPM has also been used extensively for postoperative management of articular fractures of the ankle, hip, shoulder, and fingers, in addition to the knee and elbow which have already been discussed. Acetabulum fractures frequently lead to hip stiffness post-traumatic arthritis, for instance, and can be potentially helped with postoperative CPM.[51, 52] For instance, Brumback et al. reported on 58 patients with posterior acetabulum fracture dislocations treated with ORIF and CPM, and many cases also had postoperative skeletal traction, although specific data regarding the CPM was not provided.[51] CPM was the focus of one particular study of ankle fractures treated with ORIF.[3] Farsetti and colleagues described a retrospective series of 22 patients each who underwent ORIF of a malleolar ankle fracture and had 10 years of follow-up. In the first group, CPM was applied immediately postoperatively and for three weeks. In the second group, a plaster splint or cast was applied for three weeks. Patients with CPM had higher AOFAS scores and fewer cases of osteoarthritis at 10-year follow-up than patients treated in a cast. Although this was not a controlled study and had relatively few patients, it does demonstrate the potential functional benefits of CPM compared with immobilization.

Sequelae of Articular Fractures: Arthrofibrosis and Heterotopic Ossification: Though this is not the focus of this particular paper, it is important to note that CPM is also used frequently postoperatively after open or arthroscopic treatment of arthrofibrosis of the elbow. Duration of treatment are reported from one to six weeks postoperatively, although we are not aware of any studies which have investigated CPM specifically.[53–57] Bae and co-authors were particularly aggressive and liberal with CPM treatment, applying this in the recovery room after a medial elbow release and used for 23 hours a day for three weeks, followed by nighttime use for an additional three weeks in addition to physical therapy throughout this time.[54] Alternatively, Kraushaar and colleagues did not feel that CPM was needed in a series of 12 patients with post-traumatic elbow flexion contracture treated with an open lateral release technique.[58]

Contractures of the knee are occasionally treated with the Judet quadricepsplasty, and CPM is frequently used postoperatively, as described by Ali in 10 patients in which CPM was used.[59] In this particular study, immediate CPM at a "slow" rate was applied from 0–60 degrees under epidural control and ice packs. The range of motion and rate (speed) of the CPM was gradually increased up to maximal possible flexion.

Summary

Continuous passive motion therapy clearly has some basic science and animal data to support its use in the management of articular cartilage lesions, which can be extrapolated clinically to the treatment of articular fractures. Interestingly, most clinical studies looking specifically at CPM treatment come from the total joint replacement literature in which patients without articular cartilage lesions are treated. The goals in these cases are not to improve articular cartilage repair, of course, but to essentially improve range of motion, and results have been mixed. Although CPM is used in other cases such as articular fractures, ligament reconstruction, articular cartilage repair surgery, and arthrofibrosis release surgery, it has not been well studied as a treatment for these indications. Very few studies have actually looked at CPM as a treatment modality with articular fractures, so we have very little guidance regarding the recommended time of onset, rate, duration, and other parameters that should be used. The heterogeneity of articular fractures, along with the multitude of surgical treatment factors that can affect range of motion, cartilage repair, and functional outcomes, make it difficult to study CPM from the available data in the literature. Meaningful information could potentially be obtained from a narrow injury subtype, in a randomized controlled study, just to even determine if CPM is beneficial at all, and if so, how it should be used. It appears that there is enough basic science evidence and reported use of CPM for articular fractures to warrant such a study, as we still have room for improvement with our management of articular fractures.

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Medical Student Research Project

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Efficacy and Cost Effectiveness of Prophylactic Knee Bracing in Tackle Football

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Abstract

The practice of prophylactic knee bracing has been controversial since its inception 40 years ago. Designed to prevent medial collateral ligament (MCL) injury, studies have not consistently shown that the use of prophylactic knee braces have reduced these injuries in American football. Regardless of their lack of effectiveness, preventing isolated MCL injuries need be considered in view of their relative mildness, favorable response to conservative management, lack of long-term sequellae, and early return to contact activities compared to other traumatic knee injuries. Also to be considered is the expense in that providing one non-skilled player with a pair of braces costs $500 and fitting all non-skilled players in NCAA intercollegiate football would cost approximately 30 million dollars. Considering the expense involved of fitting players with prophylactic knee braces in view of lack of evidence that they project against MCL and ACL injuries, we recommend that athletic directors, equipment managers, and coaches should take these factors into consideration in the decisions whether or not to require players to wear these braces.

Introduction

In 1988, the American Association of Orthopedic Surgery (AAOS) recommended against the use of prophylactic knee braces citing a lack of evidence of the efficacy of their use.[1] They did acknowledge that no definite conclusion about the devices could be made and that further research and testing was needed. Since this initial recommendation, the AAOS published a new statement in 2003 regarding prophylactic knee braces stating, "Prophylactic knee braces may provide limited protection against injuries to the MCL in football players."[2] However, in 2007, the AAOS has since retired this position statement and has not offered a new position on the use of prophylactic knee braces.

Despite no clear endorsement statement from the AAOS and a lack of convincing studies that demonstrate efficacy, many high school and college football programs either encourage or have mandatory usage of the braces in their programs. Many team physicians, trainers, coaches, and players believe the cost of the knee braces is justified because of claims that these braces may prevent knee injuries. However, the braces are designed only to prevent medical collateral ligament (MCL) injuries, which are relatively mild, experience a favorable response to conservative management, and lack long-term sequellae. Also, there is early return to contact activities compared to other traumatic knee injuries.[3, 4] The major knee injury that devastates most high school and college football athletes is disruption of the anterior cruciate ligament (ACL) and, on occasion, the posterior cruciate ligament (PCL), both of which have a limited potential for spontaneous healing and usually require surgery.[4] Prophylactic knee braces were neither designed to prevent ACL or PCL injuries, and no study has demonstrated evidence of their preventing these injuries.

Background

Football is a popular sport in America and it is estimated that over 1.3 million high school athletes and over 75,000 collegiate athletes play contact football in organized programs.[5] Contact football at these levels involves numerous injuries, particular to the knee in which the literature has varying estimates of occurrence from eight percent to 36 percent of all football injuries.[6]

Previously, a grade III MCL injury was considered severe requiring surgery with a resulting great loss of playing time. The lost playing time and sequellae resulted in the use of prophylactic knee braces. More recent data has afforded a better understanding of the three degrees of MCL injuries with regard to management guidelines. Greater understanding of non-operative management have substantiated that these injuries do not lead to significant time loss or long-term sequellae. Specifically, players sustaining a grade I tear return to the playing field in about 11 days, grade II in 20 days and the most severe grade III in just 34 days.[4] MCL injuries associated with tears to the ACL or PCL require operative management; however, current data indicates that prophylactic braces are not protective for these injuries.[4] ACL injuries usually occur due to a non-contact mechanism and PCL injury from anterior contact to the knee, whereas a

prophylactic brace only claims to protect injuries occurring due to lateral contact.

Prophylactic knee braces have been used in high school and college football programs since the early 1980s. The first prophylactic knee brace was developed in 1978 by George Anderson, head athletic trainer for the Oakland Raiders. The brace was developed in response to an injury to quarterback Ken Stabler, which was a double-hinged brace coined the Anderson Knee Stabler.[7] Importantly, Anderson reported that these knee braces were only effective at preventing re-injury to several players.

The Anderson Knee Stabler, along with other commercially available versions of this device, were use by other players who had never been injured in attempt to prevent MCL injuries. However, based on Anderson's report and the perceived success, the use prophylactic knee braces spread throughout college and high school football programs, and became mandatory in many programs by the early and mid 1980s.

Since the braces have come into use in the 1980s, many researchers have attempted to answer the question of whether or not these knee braces are effective at preventing MCL injuries. Table 1 summarizes the results of these studies which have no consensus and vary greatly in their conclusions. The first significant research reports came out in the mid 1980s and showed various results. A study by Teitz suggested that prophylactic knee braces did not prevent knee injuries and actually increased the risk of knee injury to the players that wore them.[8] Studies by Hewson and Rovere found no statistically significant evidence to suggests prophylactic knee bracing had any positive effect for preventing knee injuries.[9, 10] However, two studies — one by Hansen and another by Schriner — displayed statistically significant evidence that prophylactic knee braces effectively reduced the number of MCL injuries.[11, 12] Quillan, in a non-statistical study of 250 players, suggested a positive effect of prophylactic bracing.[13]

Table 1. Summary of Previous Studies and Conclusions

Author	Year	Conclusion
Hansen[11]	1985	Effectively reduces knee injuries
Hewson[9]	1986	No statistically significant evidence of a positive effect
Teitz[8]	1987	No positive effect and increases risk of injury
Rovere[10]	1987	No statically significant evidence of a positive effect
Schriner[12]	1987	Effectively reduces knee injuries
Quillian[13]	1987	Small evidence of reducing injuries
Grace[14]	1988	No positive effect and may increases risk of injury
Zemper[15]	1990	No positive effect and may increases risk of injury
Sitler[17]	1990	Effectively reduces knee injuries based on player position
Deppen[16]	1994	No statistically significant evidence of a positive effect
Albirght[19]	1994	No statistically significant evidence of a positive effect
Pietrosimone[6]	2008	No statistically significant evidence of a positive effect
Salata[18]	2010	No statistically significant evidence of a positive effect

Since 1988, many additional studies have been undertaken with varying results. Studies by Grace and Zemper indicated that the prophylactic knee braces demonstrated no positive effect in preventing injuries and data suggested an increase in the risk of knee injury.[14, 15] A study by Deppen found no statistically significant difference between the braced and non-braced players.[16] Lastly, a study by Sitler following cadets in a US military academy who participated in eight-man intramural football found a significant reduction in MCL injuries that was dependent on player position.[17] A more recent study in 2008 by Pietrosimone attempted to determine a relative risk difference between braced and non-braced players by retrospectively analyzing previous studies.[6] The authors concluded that no definitive conclusion could be drawn. The most recent study in 2010 by Salata[18] concluded that no consistent effect of prophylactic knee bracing could be determined.

Many of these studies attempted to comment on the incidence of ACL injuries between braced and non-braced players but were unable to demonstrate a statistically positive effect. Many collegiate and high school programs encourage the use of prophylactic knee braces and some programs require certain players to wear them despite no recommendation from the AAOS and a lack of evidence of the effectiveness of the braces. A typical brace such as the Bledsoe Axoim retails $500 per brace (Figure 1).

Clearly, analysis of the above cited data pools raise the question of the efficacy of prophylactic knee braces protecting against any knee injury with particular regard to the MCL. Corollary to this question are two issues: one, are MCL injuries of significance with regard to time lost and sequela; two, are the expenses of braces justified?

Methods

Relevant literature articles were found by searching the PubMed database. The database was searched by using the MeSH for knee injury, sub title prevention and control and MeSH for football. The search returned 31 results. Many of these 31 results are relevant to the study of prophylactic knee bracing. The remaining relevant articles were found by reading two relevant review articles by Requa and Pietrosimone.[6, 20] The review article by Requa provides a review of the study methods used, offering superb commentary on the limitations and difficulty of the prophylactic knee bracing studies conducted prior to 1990. After finding the studies, a level of evidence score was assigned to each study. Table 2 provides a summary each of the authors' method of study.

A search for medial collateral ligament injuries was searched using the PubMed database by searching MeSH medical collateral ligament knee subtitle injury and MeSH football injuries. Nine results were retrieved, one of which was relevant. The relevant paper talked about lateral collateral ligament (LCL) of the knee but several references in the paper were made to studies about the MCL which were very useful.

Figure 1. The Bledsoe Axiom brace, a typical prophylactic knee brace

Consultation with the head athletic trainer for the Temple University football program provided information of the cost and use of the prophylactic knee braces. A calculation of Temple University's football program of prophylactic knee bracing policy was applied to all NCAA football teams to provide aggregate cost of prophylactic knee bracing for offensive lineman in all of college football.

Results

Most of the studies were done by looking at players either non-braced or braced; however, two studies, Deppen and Albright, calculated players knee exposures and further divided the knee exposures into a non-braced and braced group with knee exposure being defined by the author and greater weight given to hours played in a game versus practice. All of the studies provided data for total MCL injuries, displayed in Table 3. Studies for which MCL injuries were defined by severity or by days missed are included in Table 4 to display the number of grade III MCL injuries. Several authors have attempted to study the effect of bracing and ACL injury prevention, summarized in Table 5.

Discussion

Most all of the studies agree that knee bracing provides no significant clinical evidence that either an MCL or ACL injury can be prevented (Table 5). Analysis of playing time lost by the worst case scenario, a grade III MCL injury, which was 34 days and has been the consistent since the 1990s.[4] The standard of care for a grade III MCL injury is an examination to ensure integrity of the ACL and PCL as well as the menisci, followed by the use of a stabilizing brace and crutches for 14 days with limited knee exercise to promote mobility. After these 14 days, the knee is usually stabilized, crutches and bracing is discontinued and rehabilitation initiated. Typically, a stationary bike is used at first, then jogging and running are introduced and, after 30 to 40 days of injury, a player can return to contact sports. A functional brace may be recommended for the remainder of the season but is usually discontinued the following season.[3, 4] This particular standard of care is the most effective management for a grade III MCL and it is significantly less expensive than the operative treatment an ACL injury requires.

The fact that prophylactic knee braces do not prevent ACL injuries and that a grade III MCL injury neither leads to extensive playing time lost nor is expensive to treat led us to question the cost to outfit a player and/or team with prophylactic knee braces. We discovered that the bracing policy is mandatory for offensive linemen at some institutions and that many programs require all non-skilled players, defined as offensive linemen, defensive linemen and linebackers, to wear prophylactic braces. Historically, offensive linemen suffer the greatest number of knee injuries via lateral contact followed by linebackers and defensive linemen.[8, 11] A typical prophylactic brace, such as the Bledsoe Axiom, costs approximately $500 for a pair. College football teams usually have 15 to 20 offensive linemen, 12 to 17 linebackers, and 12 to 17 defensive linemen on a team per year. There are currently a total of 624 D-I, D-II and D-III football teams in the NCAA. We calculated that if every college football program outfitted their non-skilled players with knee braces, it would cost between $14 and $17 million per year. Considering that braces may last less than a year and that many collegiate teams carry reserve players not on the roster and may have additional practice squads, the true cost of outfitting all non-skilled players with prophylactic braces is conservatively estimated in excess of $30 million per year.

Conclusion

Several decades of research provides no definitive conclusion regarding the effectiveness of prophylactic knee braces and injuries to the MCL. Furthermore, no study has been able to demonstrate a positive effect on ACL injury rates (Table 6). A calculation of the cost of providing all non-skilled position players in NCAA football programs with braces would cost an estimated 30 million dollars. Also to be considered is the potential exponential cost of prophylactic bracing of high school players. To be noted is that prophylactic knee bracing is not employed at the professional level.

Considering the high expense involved of fitting players with prophylactic knee braces and the lack of evidence of either MCL and ACL injury prevention, we believe that athletic directors, equipment managers, and coachers should take this into consideration in the decision-making process of whether or not to require players to wear these braces.

Acknowledgement

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Table 2. Summary of Previous Studies Methods and Level of Evidence

Author	Year	Player Level	Non-braced	Braced	Length of Study	Method	Level of Evidence
Hansen*	1985	Collegiate	329	148	4 years	Reviewed medical records and recorded number and types of knee injuries and compared braced to unbraced	II
Hewson*^	1986	Collegiate	226	224	4 years	Analyze and compare type of injury, severity, player position and days lost from injury	II
Teitz*	1987	Collegiate	7,011	4,686	2 years	Analyzed and compared type of injuries according to player position, severity, non-braced teams and braced teams	II
Rovere*^	1987	Collegiate	70	62	4 years	Comparison of knee injuries between unbraced and braced players	II
Schriner	1987	High school	1,357	433	2 years	Comparison of knee injuries between unbraced and braced players broken down by lateral force contact and medial, posterior and hyperflexion contact	II
Quillian	1987	High school	194	50	2 years	Comparison of knee injuries between braced and non-braced groups based on contact hours	II
Grace^	1988	High school	253	330	2 years	Comparison of knee injuries between unbraced and single-hinge brace, unbraced and double-hinge brace	II
Zemper*	1990	Collegiate	4,485	1,744	2 years	Comparison of total knee injuries between unbraced and braced, comparison of MCL injuries, severity of knee injuries	II
Sitler*^	1990	Collegiate intramural eight-man tackle football	705	691	2 years	Comparison of total knee injuries between unbraced and braced, type of injury and severity	I
Deppen^	1994	High school	19,458 knee exposures	21,641 knee exposures	4 years	Comparison of total knee injuries between unbraced and braced, type of injury and severity, mechanism of injury	II
Albirght*^	1994	Collegiate	76,811 knee exposures	78,911 knee exposures	3 years	Comparison of total knee injuries between unbraced and braced, type of injury and severity, mechanism of injury	II
Pietrosimone	2008	Various	Systematic review of seven studies indicated by * next to author name		Various	Compute the relative risk increase or relative risk reduction of knee injury in each of the seven previous studies	IV
Salata	2010	Various	Review of six studies indicated by ^ next to author name		Various	Review of previous results and discussion of findings	

Table 3. Summary of Previous Studies and Total MCL Injuries (Note NB Is Non-braced and B Is Braced)

Author	NB Players	MCL Injuries NB	B Players	MCL Injuries B
Hansen	329	17	148	2
Hewson	226	41	224	33
Teitz	7,011	143	4,686	175
Rovere	70	16	62	18
Schriner	1,357	85	433	10
Quillian	194	6	50	0
Grace	250	6	330	17
Zemper	4,485	69	1,744	32
Sitler	705	25	691	12
Total	**14,627**	**408**	**8,368**	**299**
Author	**NB Exposures**	**MCL Injuries NB**	**B Exposures**	**MCL Injuries B**
Deppen	19,458	12	21,617	16
Albright	76,811	47	78,911	53
Total	**96,269**	**59**	**100,528**	**69**

Table 4. Summary of Previous Studies and MCL Grade III Injuries (Note NB Is Non-braced and B Is Braced)

Author	NB Players	MCL III NB	B Players	MCL III B
Hewson	226	15	224	8
Teitz	7,011	21	4,686	19
Rovere	70	1	62	1
Grace	250	4	330	7
Zemper	4,485	6	1,744	3
Sitler	705	3	691	1
Totals	**12,747**	**50**	**7,737**	**39**
Author	**NB Players**	**MCL III NB**	**B Players**	**MCL III B**
Deppen	19,458	3	21,617	3

Table 5. Summary of Previous Studies and ACL Injuries (Note NB Is Non-braced and B Is Braced)

Author	NB	ACL Tears NB	B	ACL Tears B
Hansen	329	6	148	1
Hewson	226	6	224	5
Teitz	7,011	33	4,686	18
Rovere	70	1	62	3
Quillian	194	1	50	0
Grace	250	1	330	1
Sitler	705	7	691	2
Total	**8,785**	**55**	**6,191**	**30**
Author	**NB**	**ACL Tears NB**	**B**	**ACL Tears B**
Deppen	19,458	7	21,617	2

Table 6. Summary of Previous Studies and Detailed Conclusions

Author	Year	Total Knee Injury	Injury Severity	Recommended
Hansen	1985	Reduction in MCL and meniscus injuries	Less players needed surgery	Yes, OL and LB
Hewson	1986	No significant reduction	No change due to bracing	No, no significant effect noted
Teitz	1987	More injuries with brace on lateral contact, especially RB and DB	No change due to bracing	No will cause more injuries
Rovere	1987	More injuries with brace	No change due to bracing	No will cause more injuries
Schriner	1987	Significant reduction 5.4%	Not determined	Yes, high school only
Quillian	1987	Reduction in MCL injuries	Less severe injuries	Longer prospective study needed
Grace	1988	Increased knee injuries for single-hinge braces, no increase in knee injuries for double hinge. However, both types of braces show an increase in injury of distal leg and foot	No change due to bracing	No will cause more leg and ankle injuries
Zemper	1990	Knee injuries are higher in braced group	No change due to bracing	No more injuries are noted

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Case Report

Progressive Fusionless Correction of Adolescent Idiopathic Scoliosis with the Anterior Vertebral Body Tether: A Case Study

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Introduction

Traditionally, scoliosis has been treated with bracing or spinal fusion. Yet, bracing is not always an efficacious treatment option: psychosocial elements surrounding brace-wear exist,[1] and bracing often fails to halt curve progression.[2] Spinal fusion presents its own problems: fusion often inhibits growth over the length of the construct, can lead to the development of adjacent level disc degeneration, and cause other difficulties including decreased range of motion and decreased spinal mobility postoperatively.[3] Because of these concerns, alternative surgical approaches that permit growth of the spine and halt curve progression have been proposed. Anterior vertebral body tethering (AVBT) has been implemented as an alternative to both spinal fusion and other fusion-less techniques. The biomechanical basis for growth modulation via a flexible tether has been shown in animal models;[4] however, there is a paucity of data investigating the efficacy of tethering in human subjects. To date, one case has been reported in literature.[5] In this report, we present the first such AVBT at our institution.

Case Study

A twelve-year-and-five-month-old female presented with a right sided, 34° main thoracic curve from T6–T11 and a lumbar curve of 34° from T10–L4 (Figure 2). The patient's thoracic kyphosis was 22° (T5–T12). The patient had a Risser score of 0, and a Sanders score of 3. Flexibility of the curve was measured at 12° upon lateral bending. On forward bending, the patient's thoracic hump and lumbar prominence both measured 10°. The patient's curve magnitude and her skeletal immaturity made her a prime candidate for the AVBT procedure.

Description of the Procedure

The patient was positioned in the lateral decubitus position with the right side up. Two small working thoracoscopic portals were made in the anterior axillary line. A 15 mm working portal and a small thoracotomy incision were also made on the mid axillary line. Screw holes were drilled and tapped and a 3-prong staple was impacted into place on the anterior aspect of the vertebral bodies under C-arm guidance. 6.0-millimeter screws were placed along the length of the construct. A flexible tether (Zimmer Dynesys, Raytham, MA) was then placed through the thoracotomy site into the tulip of the superior most screw, which was then locked down with the set screw. The tether was then laid into the tulips of all the screws. Tension was then placed onto the next caudal screw (the 2nd vertebral body of the construct). Careful reduction translation force was placed onto the spine at both of these levels as the tether was tightened, and the set screw tightened at the second body. The surgery progressed in a similar fashion distally with the tether being attached at caudal levels. All levels were sequentially tensioned (Figure 1). As previously described,[5] anterior stapling of the lumbar curve was performed at this time as well. After all instrumentation was completed, global imaging of the spine in both AP and lateral views was performed; visualization of significant reduction of the curvature in the coronal plane and appropriate alignment in the sagittal plane was obtained.

Results

The main curve measured 11° intraoperatively while the patient was in the supine position. Immediately postoperatively, the patients curve measured 15° in the upright position (Figure 5). Follow-up x-rays were obtained at six weeks, three months, six months, and one year. The patient's films showed gradual and progressive correction of the coronal deformity over the course of the follow-up period (Table 1). The thoracic curve measured 13° at six-week follow-up, 10° at three months, and 6° at six months. At 12-month follow-up, thoracic kyphosis and lumbar lordosis were well maintained and the patient's main thoracic curve measured 0°, representing a 100% correction (Figure 9).

Discussion

Several fusionless surgical options for the treatment of idiopathic scoliosis have been described. Posterior approaches with growing systems are often utilized. Problems with these include the need for serial lengthening with growing rods and expansion of the Vertical Expandable Prosthetic Titanium Rib (VEPTR) system every six months (both of these necessitate additional surgery). Anteriorly, vertebral body stapling has been applied in patients with idiopathic scoliosis (and high risk for progression) as an

alternative to bracing and/or fusion. The results of stapling suggest that the technique provided good correction of the scoliotic spine, while allowing for continued axial growth; Betz et al. report a 79% success rate in thoracic curves measuring less than 35°. However, for thoracic curves greater than 35°, stapling was unsuccessful and patients ultimately required alternative treatment.[6] This led the authors to pursue anterior vertebral body tethering (AVBT) as an alternative surgical option for skeletally immature patients who are at a high risk for progression.

It is clear from our case study that the use of the AVBT was not only able to achieve an initial coronal correction, but it has been able to control and shape the growth of the scoliotic curve over time. The patient's axial growth, along with the tension created by the tether on the convex side of the curve, has resulted in a positive and progressive correction of the curve at 12-month follow-up. By partially restraining growth on one side of the spine (the coronal convexity), the technique has allowed growth on the contralateral side to reverse the abnormal scoliotic growth pattern. This treatment option addresses many of the concerns associated with other traditional surgical techniques. The treatment is fusionless and thus avoids the difficulties associated with spinal fusion, including stiffness and trunk shortening. This technique has the additional advantage of not necessitating multiple trips to the OR (as is the case with serial lengthening of the VEPTR system or growing rods).

The authors are cautiously optimistic that the use of the AVBT will ultimately prove to be a viable treatment option for skeletally immature patients. However, several unknowns still exist surrounding the AVBT technique. Some surgeons have begun using this technique in the lumbar spine; however, no data has been published reporting its efficacy in that region. Additionally, in patients who have achieved close to 100% correction (including this case), there is concern that further skeletal growth, along with the mechanical forces of the tether, will begin to create a scoliotic curve in the opposite direction. In light of this potential hurdle, a key consideration is how much "residual curve" to leave behind in an initial tethering procedure. This decision will likely hinge on how much growth the child has remaining. If over-correction does occur, it may potentially be alleviated thoracoscopically by loosening or removing segments of the tether, thus relieving the tension in one or more segments of the construct. Clearly, though, the biomechanical principles underlying the anterior vertebral body tethering technique dictate the need for increased follow-up time to characterize the temporal relationships between dynamic tethering, skeletal growth and final correction.

Figure 1. Saw-bone model of tethering construct

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Table 1. Coronal Cobb Angle

	Preoperative	Intraoperative	First Erect	6 Weeks	3 Months	6 Months	12 Months
Thoracic Cobb	34°	11°	15°	13°	10°	6°	0.6°

Figure 2. Pre-Operative Coronal 34°

Figure 3. Pre-Operative Thoracic Kyphosis 21°

Figure 4. Pre-Operative Cobb on Right Bend 12°

Figure 5. First-Erect Coronal 15°

Figure 6. First-Erect Thoracic Kyphosis 16°

Figure 7. Six-Month Post-Operative Coronal 6°

Figure 8. Six-Month Post-Operative Thoracic Kyphosis 22°

Figure 9. Most Recent Coronal Cobb 0°

Figure 10. Most Recent Thoracic Kyphosis 23°

Review Article

Connective Tissue Growth Factor (CTGF): Current Understanding and Clinical Implications in Bone Disorders

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Abstract

It is well established that the matricellular protein connective tissue growth factor (CTGF) is produced in bone during skeletal development and fracture healing. While its importance in skeletal formation has been clearly shown through the use of genetically engineered mouse models in which CTGF production is ablated, the ramifications for targeting CTGF clinically remain controversial. Since a monoclonal antibody targeting CTGF is currently in clinical trials for the treatment several non-skeletal disorders, it is critical that we identify any potential application for targeting CTGF clinically in bone. In this article, we provide our current understanding of the role of CTGF in bone formation and potential clinical implications involving it as a target in treatment modalities.

CTGF: A CCN Family Member

The 38kDa connective tissue growth factor (CTGF) protein was first identified in the conditioned media of human umbilical vein endothelial cells and given its name due to the mitogenic role it played in these cells.[1] A role for it in bone development was demonstrated in our lab using a rat osteopetrosis model in which CTGF was shown to be highly expressed in bones.[2] The stimulation of CTGF expression by transforming growth factor beta (TGF-β), the most potent inducer of CTGF expression, was first demonstrated in human skin fibroblasts during wound repair *in vivo* where there is a coordinated up-regulation of TGF-β followed by CTGF expression.[3] In addition to TGF-β, CTGF is also upregulated by other growth factors and is ultimately secreted into the extracellular matrix (ECM), where it exerts its effects in an autocrine and paracrine fashion on cells through interaction with other ECM components; this is made possible by its modular structure.

The CTGF transcript contains five exons, which code for a signal peptide and four modules. Module I is an insulin-like growth factor (IGF)-binding domain, Module II a von Willebrand type C (vWC) domain, Module III a thrombospondin-1 (TSP-1) domain, and Module IV a C-terminal domain containing a putative cysteine knot.[4–6] CTGF has been grouped with other proteins with similarly conserved modules into the CCN family of proteins. Named for the three original members — Cysteine-rich 61 (Cyr61), CTGF, and Nephroblastoma overexpressed (Nov) — the CCN family also includes the Wnt-induced secreted proteins (WISP) 1–3.[7] CCN proteins regulate an array of cellular and physiologic functions, including those crucial for bone formation, growth, and maintenance.[8]

It is important to note that to date no single, unique CTGF receptor has been identified. Instead CTGF exerts cellular effects by binding to cell-surface integrin receptors and interacting with co-receptors in the ECM. At least eight types of integrins have been shown to bind to CCN proteins.[9] Additionally, CTGF has been shown to bind different integrin complexes on the same type of cell.[8] CTGF also interacts with multiple types of co-receptors. These include heparan sulfate proteoglycans (HSPGs), low-density lipoprotein (LDL) receptor-related proteins, and the neurotrophic tyrosine kinase receptor type 1 (NTRK1 or TrkA).[10] Through its interaction with these integrin receptors and co-receptors, CTGF functions in three general ways: 1) CTGF signals in an effector cell through direct integrin binding on the cell surface; 2) can alter the biologic activities of growth factors and cytokines through signaling crosstalk; and 3) CTGF can both regulate the expression of biologically active molecules (e.g. growth factors, cytokines), and functionally interact with them in the ECM to affect their bioavailability and activity. As a result, the complex interaction of CTGF with other molecules results in a functional versatility in a cell- and context-specific manner.

CTGF Is Required for Skeletal Development

A role for CTGF in skeletal tissues first emerged from studies demonstrating its expression in developing cartilage, bone, and teeth.[11–14] However, the key finding for the indispensability of CTGF in skeletogenesis came with the generation of genetically engineered mice lacking CTGF production. These CTGF knockout (KO) mice have provided great insight into the importance of CTGF in normal skeletal development. The initial study demonstrated that CTGF KO mice are born with multiple skeletal dysmorphisms, including bends (or kinks) in specific long bones, craniofacial

abnormalities, and misshapen ribs.[12] CTGF KO mice die shortly after birth due to respiratory distress; this is believed to be the result of the misshapen ribs as well as pulmonary hypoplasia.[12, 15] Since these mice cannot be studied postnatally, the lack of CTGF in adult bone maintenance and fracture repair has not been pursued extensively. This gap in our understanding of CTGF in adult bone constitutes a difficulty when considering the application of a monoclonal antibody targeting CTGF for clinical treatments (see below). Our laboratory recently demonstrated that the role of CTGF in prenatal bone development is skeletal site-specific, such that the loss of CTGF, while critical for the proper formation of some bones (e.g. tibiae), is not necessary for normal formation of others.[16] This adds yet another level of complexity in understanding the role of CTGF in skeletal tissues, one that is necessary should it be used in clinical applications.

The Osteoinductive Promise of CTGF

CTGF is produced and secreted by osteoblasts and has been shown to stimulate osteoblast differentiation, matrix production, and differentiation *in vitro*.[2, 13, 17–20] Considering the apparent beneficial effects of CTGF on osteoblast differentiation and bone formation, studies have tested applications of its use in bone regeneration to promote bone healing or new bone formation. Injection of recombinant CTGF (rCTGF) into the marrow cavity of rat femurs elicited an osteoinductive response in the form of osteoblast differentiation and active bone formation.[2, 13] When a hydroxyapatite carrier loaded with CTGF was implanted into bone defects within a rabbit mandible, CTGF significantly enhanced the proliferation and migration of human bone marrow stromal cells, induced cell invasion and enhanced bone formation compared with the carrier alone.[21] Using the intractable bone defect model, treatment with rCTGF induced the osteoblast mineralization markers and enhanced the bone regeneration.[22] The majority of *in vivo* and *in vitro* studies support an anabolic role for CTGF on bone formation, and therefore, this factor is a candidate for the development of novel clinical therapeutic approaches to stimulate bone formation.

CTGF Promoter Polymorphism and Systemic Sclerosis

Recent evidence demonstrates that a polymorphism in the CTGF gene promoter is associated with a susceptibility to systemic sclerosis (SSc). The polymorphism constitutes a G-945C substitution, the effect of which is to decrease the binding of the key transcriptional repressor, SP3, resulting in increased expression of CTGF.[23] However, this (G-945C) polymorphism does not correlate with increased plasma CTGF levels.[24] SSc, also known as scleroderma, is a heterogeneous disorder of the connective tissue and includes in its disease progression immune activation, vascular damage, and eventual tissue fibrosis.[25] Due to the lack of efficient antifibrotic therapeutics, severe SSc results in mortality due to the fibrosis and subsequent loss of function of skin, vasculature, musculoskeletal system, and internal organs.[23, 25] In addition to the well-known fibrotic changes seen in SSc, bone mineral density (BMD), bone mass, and bone quality in these patients are deleteriously affected,[26, 27] including both cancellous and cortical bone.[28] Further studies are necessary to determine if there is a direct link between the G-945C CTGF promoter polymorphism and effects on bone in SSc patients.

WISP-3/CCN6 and Progressive Pseudorheumatoid Dysplasia

Members of the CCN family, such as CTGF, may play a role in regulating the expression of other family members. Importantly, this has been suggested from studies using the CTGF KO mouse in which Nov/CCN3 expression increased in chondrocytes in the absence of CTGF.[29] Therefore, it is becoming increasingly evident that examining the expression levels of all six CCN family members is prudent in cases of individual mutations causing skeletal abnormalities. In 1999, mutations in Wisp-3/CCN6 were identified as the molecular cause for the syndrome Progressive Pseudorheumatoid Dysplasia (PPD). PPD is an autosomal recessive disorder characterized by juvenile onset arthropathies and progressive erosive bone and joint changes.[30] However, when mice were generated with the mutations seen in human PPD, the skeletal function was normal.[31] This highlights the fact that murine models involving genetic mutations in CCN proteins do not always recapitulate human pathologies. Further investigation is necessary to determine if any CTGF expression is affected as a result of Wisp-3 mutations in PPD.

Current Anti-CTGF Treatment: FG-3019

Levels of CTGF have been shown to be markedly elevated in various injured tissues that develop fibrosis including the skin, kidney, liver and lung.[32–36] More recently, CTGF overexpression has been implicated in the pathophysiology of dystrophic skeletal muscles where it is believed to contribute to the deterioration of skeletal muscles and their function in addition to mediating the ensuing fibrosis of the damaged muscle tissue.[37] Clinical trials are currently underway using a monoclonal antibody (FG-3019) that recognizes module II of human and rodent CTGF as a novel therapy to treat patients with diabetes, advanced kidney disease, pancreatic cancer, idiopathic pulmonary fibrosis.[38] This antibody has also been used to treat CTGF-expressing tumors in mice, where it abrogated CTGF-dependent pancreatic tumor growth and lymph node metastasis without any toxic side effects in mice.[39] FG-3019 has also been used as a therapy in a mouse model of Duchenne muscular dystrophy, where it reversed the fibrosis of muscular tissue and even allowed return of skeletal muscle function (personal communication, Dr. Enrique Brandan). These studies support the concept of using drugs that specifically target CTGF as a treatment for

various human diseases. However, the effects of FG-3019 on underlying bone have not yet been investigated.

Targeting CTGF Clinically: A Paradox

The utility of targeting CTGF clinically to treat conditions of insufficient bone formation, while ripe with potential, is still far from being a complete picture. As mentioned previously, studies in which rCTGF was injected into the marrow cavity of rat femurs demonstrated an anabolic response to CTGF in bone formation.[2, 13] However, since the functional diversity of CTGF largely depends on the matricellular molecules with which it interacts, the anabolic nature of CTGF in bone is likely contingent upon the presence and/or absence of specific molecules at a target skeletal site; therefore, the effect of CTGF on bone would be variable from site to site. To illustrate this, consider the interaction of CTGF with the TGF-β and bone morphogenetic proteins (BMP) pathways. While both of these pathways are critical in bone formation, it has been shown that CTGF can positively enhance TGF-β signaling through interactions with TGF-β1 while inhibiting BMP receptor signaling through interaction with BMP-4.[40] Furthermore, we have demonstrated that treatment of primary osteoblasts that lack CTGF (isolated from CTGF KO mice) with rBMP-2 causes enhanced differentiation and signaling when compared to control osteoblasts (isolated from wild-type mice; see paper by Mundy et al. in this edition). These data suggest that CTGF acts to inhibit the anabolic effect of BMP-2 on bone formation.

Herein lies the current paradox of targeting CTGF clinically in bone: how is it that CTGF alone produces osteoinductive effects, while also potentially countering the well-established osteoinductive effects of BMP-2? While there is insufficient research evidence to currently tease apart this discrepancy, both have current clinical implications. As CTGF expression normally increases during fracture repair, one could postulate that abrogation of CTGF signaling through FG-3019-mediated blockade would negatively affect fracture healing and potentially hasten development of age-related osteoporosis.[13, 14, 41, 42] This would present a serious detractor to FG-3019 therapy, particularly in postmenopausal women. Additionally, knowledge of the CTGF-BMP interaction could identify a potential use for the addition (or blockade) of CTGF in concert with recombinant BMP2 (rBMP-2) administration in treatment of bony defects and malunions. To fully understand the therapeutic potential of CTGF in bone formation, studies must utilize the following: 1) animal models simulating various clinical scenarios, such as fracture repair and osteoporosis; and 2) local or global treatment using rCTGF or FG-3019 with or without rBMP-2. Once results from these *in vivo* models are obtained, only then can one understand the clinical applications of CTGF for treatment of patients with bone disorders.

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Senior Abstract

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Are Young Adults With Low Energy Distal Radius Fractures Vitamin D Deficient? A Prospective Pilot Study

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Introduction

Low serum levels of Vitamin D (25-hydroxyvitamin D_3) have been associated with low energy fractures in the elderly; however, no investigations to date have correlated Vitamin D with low energy fractures in young adults. The purposes of this study were to 1) measure the serum levels of 25-hydroxyvitamin D_3 in young adults who sustained a low energy distal radius fracture and compare those values to that of healthy individuals without a history of fracture; and 2) determine the prevalence of vitamin D deficiency in this population.

Methods

A single-center, prospective study of low energy distal radius fractures was performed at an urban, level I trauma center in the northeastern region of the United States from 2011–2012. All subjects were aged 18–45 years. Demographic information such as age, body-mass index, race, gender, medical history, and history of previous fracture were recorded. For the study group, all patients were tested for serum 25-hydroxyvitamin D_3 within 30 days of the injury; patients who sustained an injury via a high-energy mechanism were excluded. For the control group, individuals were selected from a database of healthy patients followed by the internal medicine service; they were excluded if a history of comorbidity or previous fracture was identified.

Results

A total of 15 distal radius fractures and 67 healthy controls met inclusion criteria. The overall range of 25-hydroxyvitamin D_3 level was 7.0–50.2 ng/mL, and the average measurement was 22.4 ng/mL in the control group and 21.4 ng/mL in the study group; these differences were not statistically different ($p = 0.9761$). In patients who sustained a distal radius fracture, vitamin D levels were categorized as the following: deficiency in 13.3%, insufficiency in 46.6%, and adequacy in 40.0%. Of the fracture cases, seven of 15 were managed by operative fixation, and patients who underwent surgery did not have significantly different values than those treated by nonoperative management ($p = 0.7788$).

Conclusions

The overall serum 25-hydroxyvitamin D_3 levels for young adults in this region were in the low-normal range. Patients who sustained a low energy distal radius fracture did not have significantly lower vitamin D levels than relatively similar, healthy patients without a history of fracture.

Senior Abstract

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Nerve and Tendon Injury with Percutaneous Fibular Pinning: A Cadaveric Study

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Objective

The purposes of this study were to measure the average distance from a percutaneous pin in each quadrant of the distal fibula to the sural nerve and nearest peroneal tendon, and define the safe zone for pin placement as would be used during surgery.

Method

Ten fresh-frozen cadavers underwent percutaneous pin fixation into four quadrants of the distal fibula. The sural nerve and peroneal tendon were identified as they coursed around the lateral ankle. Distances from the K-wire in each quadrant to the anatomic structure of interest were measured.

Results

Average distances (mm) from the K-wire to the sural nerve in the anterolateral, anteromedial, posterolateral, and posteromedial quadrants were 19.1 ± 8.9 (range, 5.1–35.5), 12.8 ± 8.2 (range, 0.3–27.8), 12.6 ± 6.8 (range, 3.0–27.8), and 5.9 ± 5.5 (range, 0.1–19.9), respectively. Average distances from the K-wire to the nearest peroneal tendon in the anterolateral, anteromedial, posterolateral, and posteromedial quadrants were 15.7 ± 4.4 (range, 9.5–23.1), 11.9 ± 5.2 (range, 3.2–21.7), 6.3 ± 3.9 (range, 0.1–14.4), and 1.0 ± 1.6 (range, 0–5.6), respectively.

Conclusions

Percutaneous pinning of distal fibula fractures is a successful treatment option with minimal complications. Our anatomical study found the safe zone of percutaneous pin placement to be in the anterolateral quadrant. The sural nerve can be as close as 5.1 mm and the peroneal tendons as near as 15.7 mm. In contrast, the posteromedial quadrant was associated with the greatest risk of injury to both the sural nerve and peroneal tendons.

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Is Antibiotic Prophylaxis Necessary in Elective Soft Tissue Hand Surgery?

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Background

Antibiotic prophylaxis for clean soft tissue hand surgery is not yet defined. Current literature focuses on overall orthopedic procedures, traumatic hand surgery, and carpal tunnel release. However, a paucity of data exists regarding the role of antibiotic prophylaxis in a broader variety of soft tissue hand procedures. The goal of the current study was to evaluate the rates of surgical site infection following elective soft tissue hand surgery with respect to administration of prophylactic antibiotics.

Methods

A multicenter, retrospective review was performed on 600 consecutive elective soft tissue hand procedures. Procedures with concomitant implant or incomplete records were excluded. Antibiotic delivery was given at the discretion of the attending surgeon. Patient comorbidities were recorded. Outcomes were measured by the presence of deep or superficial infections within 30 days postoperatively.

Results

The four most common procedures were carpal tunnel release, trigger finger release, mass excision, and first dorsal compartment release. The overall infection rate was 0.66%. All infections were considered superficial, and none required surgical management. In patients who received antibiotic prophylaxis (n = 212), the infection rate was 0.47%. In those who did not receive prophylaxis (n = 388), the infection rate was 0.77%. These differences were not statistically significant (P = 1.00).

Discussion

Most of literature has evaluated the efficacy of antibiotics in hand surgery as a function of trauma or carpal tunnel syndrome. We aimed to expand the body of knowledge by studying a variety of procedures. With increasing threats of withholding reimbursement for non-compliance with SCIP measures, additional data will be useful for guiding future health policy. Furthermore, with increasing antimicrobial resistance, judicious use of antibiotics is warranted. Limitations include retrospective design, lack of randomization, and potential type II error.

Conclusion

The overall rates of infection following elective soft tissue hand surgery are very low. Antibiotics did not appear to confer additional protection from surgical site infection.

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The Etiology of Childhood Limp Presenting to a Tertiary Care Pediatric Emergency Department . . . Risk Factors Predictive of Hospital Admission

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Background

The differential diagnosis for a child with a limp/inability to bear weight is extensive. While many etiologies of limp do not require urgent attention, several orthopedic conditions require hospital admission for management. The purpose of this study is to identify the etiologies of childhood limp presenting to a tertiary care pediatric emergency department, and to isolate patient factors that predict need for urgent orthopedic care.

Methods

Electronic medical records of all patients presenting to a tertiary care pediatric emergency department from 1/1/2010 to 4/1/2010. The search identified 16,056 patients of which 1,776 had a musculoskeletal complaint; of those patients, the medical record was evaluated to delineate individuals with a lower extremity injury, limp, and/or inability to bear weight. These patients underwent a full chart review to determine the exact etiology. Univariate analysis and multiple logistic regression were used to compare groups.

Results

Respiratory complaints were the most common reason for presentation to the emergency department (4,173 patients, 26%), followed by gastrointestinal/abdominal (2,538 patients, 16%), ear, nose, and throat (2,345 patients, 15%), musculoskeletal (1,776 patients, 11%) and dermatological (1,104 patients, 7%). Of the musculoskeletal complaints, 779 patients had a lower extremity injury, limp and/or inability to bear weight. The most common diagnosis was sprain/strain (205 patients, 26%). This was followed by contusion (148 patients, 19%), fracture (110 patients, 14%), cellulitis/abscess (73 patients, 9%), and abrasion/laceration/puncture (61 patients, 8%). Transient synovitis was discovered in 15 patients (1.9%), and septic arthritis in 2 patients (0.3%). An ingrown toenail or avulsion of toenail was found in 14 patients (1.8%). Other causes of limp included animal bite (6 patients, 0.8%) back spasm (5 patients, 0.6%), sickle cell crisis (5 patients, 0.6%), apophysitis (4 patients, 0.5%), burn injury (3 patients, 0.4%), frostbite (2 patients, 0.3%), slipped capital femoral epiphysis (SCFE) (1 patient, 0.2%), psoas abscess (1 patient, 0.1%), deep venous thrombosis (1 patient, 0.1%), rhabdomyolysis (1 patient, 0.1%), testicular torsion (1 patient, 0.1%). Overall, 59 patients (7.6%) who presented with a complaint of a limp were subsequently admitted. These patients represented only 0.4% of the patients who presented to the emergency department. The average age was 8.5 ± 5.4 years old. Duration of symptoms had a mean of 3.1 ± 7.9 days. In regards to mechanism of injury, 30 patients (51%) had a traumatic event and 29 patients (49%) had an atraumatic onset. The most common admitting diagnosis was fracture (21 patients, 36%), followed by infection which included cellulitis/myositis/abscess/psoas abscess/bacteremia with foot contusion/septic joint (16 patients, 27%), transient synovitis (5 patients, 8.5%), sickle cell crisis (4 patients, 6.8%), SCFE (1 patient, 1.7%).

The patients admitted differed significantly from those not admitted in regards to average age, mechanism of injury, presence of a fever, inability to bear, whether or not there was a past medical history, if advanced imaging was obtained, serum white blood-cell count, and if laboratory workup was performed. Multivariate analysis revealed positive clinical predictors of admission to be inability to bear weight, presence of a fever, younger age, and atraumatic mechanism of injury.

Conclusions

The wide differential diagnosis for a child presenting with a complaint of limp/inability to bear weight on the lower extremity makes efficient and accurate diagnosis challenging. In the emergency department, traumatic etiologies predominate with sprain/strain, contusion, and fracture accounting for nearly half of all visits. A thorough history and physical exam, coupled with radiographs, is sufficient to diagnose limp in most cases. Resources such as laboratory studies and advanced imaging are best utilized for younger children without a history of trauma, with inability to bear weight, and a fever upon presentation to assist in establishment of diagnoses that require urgent treatment and/or hospital admission.

Special Event

John Lachman Lecture at the Pennsylvania Orthopaedic Society Fall Meeting

This year's fall 2012 meeting of the Pennsylvania Orthopedic Society meeting titled "Sports Medicine: From Sidelines to Surgery and Back Again!" held an impressive line-up of speakers, including our own Dr. J. Milo Sewards who delivered the above-mentioned annual Lachman Lecture. Beginning with an intriguing history from ancient wars to the introduction of general anesthetic in the Crimean War, the advancements in hand surgery, intramedullary nailing and antibiotics in WWII to the evolving MASH units and urgent evacuations in Vietnam, he described the now-modern TCCC, or Tactical Combat Casualty Care, and the role of damage control orthopedics in the Middle East. While no definitive implantable fixation is used in the combat zone for our troops, the methods and tools of stabilization were outlined along with a myriad of pictures illustrating the trauma that is seen and how it is compared to certain extreme cases at our own home institution. A stimulating discussion was held afterwards describing the ways in which both local fighting militia and insurgents are treated at our surgical units in the combat zones, and the unique ways these cases must be treated. We are all proud of Dr. Sewards' service to our country and honored to have him working and teaching at Temple.

Colin Mansfield, MD

Gregory Gallant, MD, MBA, past president of the Pennsylvania Orthopaedic Society, and J. Milo Sewards, MD

Special Event

The Fourth Annual Delaware Valley Orthopaedic Trauma Symposium

The Fourth Annual Delaware Valley Orthopaedic Trauma Symposium was held on June 15th–16th, 2012. The event took place at the Temple University School of Medicine and was organized by the course chairmen, Dr. Saqib Rehman, Orthopaedic Traumatologist and Assistant Professor of Orthopaedic Surgery and Sports Medicine at Temple University Hospital, and Dr. Asif Ilyas, Associate Professor and Director of the Hand and Upper Extremity Surgery Fellowship at the Rothman Institute. The event was highly attended by athletic trainers, physicians' assistants, local residents and attendings. The day was greatly successful due the efforts of the 20 plus moderators who were able to provide their expertise on various topics. Guest faculty included Peter Cole, MD, Chief of Orthopaedic Surgery at the University of Minnesota as well as David Ring, MD, PhD, Director of Hand Research at Massachusetts General Hospital. This year, the focus of the symposium was on Upper Extremity Fracture Management: Tips and Techniques. Numerous topics were covered including, complex upper extremity injuries, fractures about the elbow, scaphoid and carpal injuries and a plethora of other subjects involving adult and pediatric upper extremity injuries. To supplement the lectures were workshops equipped with sawbones and various implants as well as lectures and clinical case presentations and discussions. The hands-on experience provided excellent opportunity to practice surgical technique as well as avoidance of certain pitfalls that are often encountered in surgery. Onsite were numerous orthopaedic vendors debuting some of their products such as implants and educational textbooks. Furthermore, research posters from Temple and many other local institutions were on display. Overall, the event was well orchestrated and provided an excellent opportunity to enlighten the orthopaedic and medical community on conditions affecting the upper extremity. With such a successful and well-attended event, we look forward to what this year's 2013 symposium will bring.

Emmanuel Atiemo

Special Event

The Howard H. Steel Lecture at the Philadelphia Orthopaedic Society

Presented by:

J. Richard Bowen, MD
Professor, Alfred I. DuPont Institute

"Adult Manifestations of Childhood Hip Diseases"

Another fantastic installment of the annual Howard H. Steel Pediatric Lecture occurred this year. As Dr. and Mrs. Betty-Joe Steel invited the Temple juniors to eat dinner at their table, Mrs. Steel recounted the many stories they have from their vacation ranch in Montana and volunteered some of their early stories from Seattle over the table's very generous glasses of wine and steak buffet.

The lecture following dinner was just as lively and jovial, being presented by the esteemed Dr. J. Richard Bowen. After recounting a case in which he was able to scrub in with the famed Dr. Steel early in his career (and managed to hold an extremely large leg for the entirety of the case without an overly amount of mishap), he delved into a stimulating set of cases. The crowd all enjoyed hearing about Sloshy Steele, the Dega Squirt, Bony Acetabulum and the Fallen Pelvis. In all, we were able to cover his three main talking points of DDH, FAI, and Necrosis. In the end, a stimulating discussion rounded out another successful and humbling Howard Steel Pediatric Lecture, with a round of applause and ovation for both the Guest Speaker and the great man for which the lecture was named.

Colin Mansfield, MD

Front Row: Mrs. Betty-Jo and Dr. Steel; Back row: Matthew L. Ramsey, MD, President of Society; J. Richard Bowen, MD, Guest Speaker; and Donald W. Mazur, MD, Board of Directors, Program Chair

Special Event

Pennsylvania Orthopaedic Society Spring Meeting

The Pennsylvania Orthopaedic Society (POS) hosted its annual Spring Meeting in Miami, Florida at the legendary Fontainbleu Hotel Miami Beach. It seemed only fitting that PA's best and brightest musculoskeletal specialists would gather around the luxurious poolside area of the Fontainbleu, which was featured in bad-boy blockbuster films such as *James Bond-Gold Finger, The Bodyguard, The Specialist,* and *Scarface.* Joining the ranks of those great men of style at the Fontainbleu poolside bar were Temple Orthopaedics Chairman Joe Thoder and resident Rick Tosti, who were obligated to imbibe "something more fruity" than the usual choice lagers (see photo). Shortly thereafter, they were joined by faculty members, Alyssa Schaffer and Wade Andrews, at the Gotham Steakhouse.

The meeting, entitled "Controversies in Upper Extremity Surgery: East vs. West," featured debate-style didactics on various controversial topics. Dr. Thoder was invited to debate Dr. Anthony Romeo, team physician of the Chicago White Sox, on the merits of open reduction internal fixation versus total elbow arthroplasty for acute fractures of the distal humerus. Although Dr. Thoder was our only faculty speaker, Temple Orthopaedics had a significant presence at the meeting. Ortho Resident Rick Tosti presented research entitled "Is Antibiotic Prophylaxis Necessary in Elective Soft Tissue Hand Surgery?" The project was recently given the honor of "Best Presentation" at the Hand and Wrist section at the American Academy of Orthopaedic Surgeons (AAOS) 2012 meeting, and it was similarly well received at the POS. Furthermore, alumnus Asif Ilyas was the co-chairman of the program, moderator of the section on elbow controversies, and speaker of exploring radial nerve palsies after fractures of the humerus. Additionally, alumnus David Yucha was invited to speak about biceps tenodesis in the 40 year old and debated against the option of SLAP repair. Last, former faculty member and sports fellow, John Kelly, lectured on the value of MRI versus ultrasound the diagnosis of rotator cuff tears. Truly showing that old habits die hard, he began his discussion with a video of a chimpanzee urinating a clear yellow stream into its mouth and said "this is the value of ultrasound in diagnosing cuff tears . . . be a man and order an MRI!"

Rick Tosti

Special Event

2012 American Academy of Orthopaedic Surgeons Meeting

Temple Orthopaedics was well represented at the 2012 American Academy of Orthopaedic Surgeons meeting in San Francisco. The chief resident class of 2012, including John Fowler, John Richmond, Jung Park and Nate Bodin, made the trip to the Bay Area and certainly made the most of the experience. In addition to going to several lectures at the San Francisco Convention Center, they took full advantage of beautiful Northern California by taking a day trip with several of the faculty to Napa Valley for a wine tasting tour. They also "shacked up" in quite a posh suite in the downtown San Francisco with a lovely, picturesque view of the City by the Bay.

The meeting itself featured three poster presentations, two podium presentations and a scientific exhibit from the Temple University Department of Orthopaedics and Sports Medicine. Rick Tosti, second-year resident, gave an extremely well-received presentation on his paper, *Is Antibiotic Prophylaxis Necessary in Clean Soft Tissue Hand Surgery?,* a paper which later went on to get published in the journal, *Orthopedics.* John Fowler presented a paper from the Kinesiology Department at Temple University on *Athletic Induced mTBI and Catastrophic Intracranial Injuries: Helmet Efficacy and Predisposing Profiles.* Third-year resident Rich Han presented his poster titled, *Evaluation of Glenohumeral Bone Defects in Shoulder Instability: Interobserver Reliability Across Modalities.* Fourth-year resident Emmanuel Atiemo displayed his poster, *Why Do Corticosteroids Work in Stenosing Tenosynovitis: Histologic Evaluation of the Tenosynovium.* Fellow fourth-year resident Matt Kleiner presented his poster, *Enoxaparin and Warfarin for VTE prophylaxis in THA: To Bridge or Not to Bridge.* Finally, faculty member Saqib Rehman and Rich Han enlightened passers-by with a captivating exhibit conceived of Temple's intimate experience with orthopaedic injuries from penetrating gun shot wounds titled, *Ballistics: Current Trends in Firearms (Experiences from Temple University Hospital).*

Congratulations to all of the participants for their hard work and dedication to their research and for representing Temple well. Keep up the good work!

Matthew T. Kleiner

Special Event

Resident Research Day 2012

Held on April 21, 2012 in the Clancy Conference Room, Resident Research Day for Temple University Department of Orthopaedic Surgery and Sports Medicine displayed the most recent contributions to the department's excellent research tradition. The program cover featured a drawing of Dr. John Lachman making a teaching point, and each presentation demonstrated the pursuit of better understanding of orthopaedic medicine and more effective clinical solutions that his legacy engenders.

The program started with an excellent grand rounds presentation by Nancy Pleshko, PhD, a professor in the Department of Bioengineering at Temple University and director of Temple's Tissue Imaging and Spectroscopy Laboratory (TISL). Dr. Pleshko is a leading researcher in cartilage imaging and analysis, and her talk, "Cartilage Degradation and Repair: Progress Towards Clinical Spectroscopic Assessment," reviewed the development of infrared spectroscopic analysis to evaluate cartilage lesions and cartilage repair techniques. In addition to educating the crowd regarding the molecular properties of cartilage that make it such an important factor in orthopaedic pathology, Dr. Pleshko discussed potential clinical benefits of translating her bench laboratory techniques directly to *in vivo* analysis through the development of spectroscopic probes. Throughout her talk, Dr. Pleshko was able to keep focus on the link between basic science principles and their clinical applications. And being from our home institution, Dr. Pleshko and the TISL offer endless possibilities as a resource for collaboration in the future.

The day continued with strong resident presentations that addressed many hot topics in modern orthopaedic practice. Matthew Kleiner, MD addressed postoperative anticoagulation protocols with his presentation "The Lovenox Leak: To Bridge or Not to Bridge." Richard Han, MD presented "Evaluation of Glenohumeral Bone Defects in Shoulder Instability: Inter-observer Reliability Across Modalities," which had previously garnered a lot of interest as a poster presentation at the AAOS national meeting. And Samuel Popinchalk, MD gave a talk titled "Development of a Pollicization Clinical Outcomes Measure" that tied in unique practices at Temple's affiliate, Shriners Hospital for Children. A highlight of this section of the program was the presentation, "A Review of Atypical Femoral Fractures from a Tertiary Care Teaching Hospital. Is there an Alarming Trend?" by John-David Black, MD. Dr. Black is a resident at St. Luke's University's Department of Orthopaedic Surgery. His inclusion in the program brought in new research and fresh perspective from an area institution outside of the Temple network, and the department was happy to welcome him. It also opened up discussion regarding the "Own the Bone" program, which the department has been trying to initiate at Temple.

Resident Research Day also serves as a culmination for the hard work of each class of senior residents. The PGY-5 class once again showed that their leadership skills extend from the hospital wards and the operating rooms to the laboratory. Presentations were as follows: "Flouroscopic Evaluation of DRUJ Violation with Plating of Distal Radius Fractures" by Nathan Bodin, MD; "Bacterial Adherence to Barbed Monofilament Suture in a Contaminated Wound Model" by John Fowler, MD; "Biomechanical Comparison of Locked Plating and Spiral Blade Retrograde Nailing of Supracondylar Femur Fractures" by Jung Park, MD; and "Access to Care Following Acute Anterior Cruciate Ligament Injury: 2 Year Evaluation of a Single Urban Academic Center" by John Richmond.

In the end, presentations were judged by a panel that included Dr. Pleshko and numerous department attendings. Drs. Fowler, Richmond, and Park were awarded first, second, and third place prizes respectively. On a day that showcased the department's strong research initiative, there were also intriguing collaboration opportunities, interesting outside perspectives that promoted meaningful academic discussion, and an award-winning send off for the PGY-5 class. And the prevailing sentiment of the day was excitement for what the department can produce over the next academic year.

Scott Barbash, MD

Special Event

Alumni Day 2012

This year's Alumni Day began on a rainy Friday morning on May 4th, 2012 with a record number of attendees gathering at Lulu Country Club in Glenside, PA. A long line of Temple physicians were in attendance, from the class of 1968 to the newly established interns who were just finishing their first year. A series of lectures from program alumni, including Glenn Lieberman, MD, Joseph Milo Sewards, MD and Neil MacIntyre, MD, were given on trauma, joint replacement, and other current topics.

The day was dedicated to Dr. Edward Resnick. Dr. Resnick was a compassionate man who devoted his life to orthopedics and his patients. He was humorous and witty, and truly enjoyed educating his residents. He worked as an x-ray technician in the Army Medical Corps in Europe from 1944 to 1946 and travelled to Kenya, Tunisia, Peru, and the Dominican Republic to share his orthopaedic knowledge with other physicians and healthcare workers.

By the time lectures and lunch finished, the sun had swept the rains with temperatures climbing to a beautiful 85 degrees. The golf course, designed by legendary architect Donald Ross, was host to several foursomes of golfers competing for awards such as Closest to the Pin and Longest Drive. Residents uncertain of their golfing skills took to the fairways on carts, but none could be persuaded to caddy.

Because I know stories change face over time, I feel as though I should put this in writing: Dr. Milo Sewards, our program director, won the Closest to the Pin award but Sam Popinchalk, PGY3 and resident golf favorite, was sidelined due to an injury which allegedly occurred just hours prior to the event as they crossed paths in the parking lot.

At cocktail hour and dinner, the current residents listened to Dr. Thoder, Chairman of Temple Orthopaedics, reminisce with his past resident classmates about "the good old days." As they laughed and exchanged stories, it was clear that our orthopaedic program is a second family few are lucky to experience, regardless of where graduates start their new careers or the fields they pursue.

Justin Iorio

Special Event

Second Annual Ponderosa Bowl

December 8, 2012

On an early December morning on the muddy plains of the Ponderosa, 12 gathered for the Second Annual Ponderosa Bowl (formerly the Shrine Bowl). The Cherry Team was led by veteran and captain John Fowler while the White Team was spearheaded by the triple threat of chief residents Katherine Criner, Joseph Dwyer and Matthew Kleiner. It was a back and forth battle during the first half with a tie game of 20–20 at the midway point. The White Team started the second half with a long scoring drive, highlighted by Stephen Refsland's personal foul for an inappropriate "high tackle" on Criner which kept the drive alive. International threat, Liam Woozley, scored a play later on a short wide receiver screen to take the lead 28–20. However, at the end of the day, the depth of the Cherry squad proved too much as they scored four consecutive touchdowns to close the game. Craig Steiner was able to bounce back one play after an embarrassing and costly (ruined jeans) slip in the mud to throw an essential block on the go ahead score by Rookie of the Year Jim Lachman. It was all over for the White Team when a questionable pass interference call on Christopher Haydel in the defensive red zone led to Fowler's second score on the day, putting the game well out of reach. Fowler and Lachman each had multiple scores on the day, allowing the Cherry Team to take home the coveted Joseph Torg Cup. Final score: Cherry 48–White 28.

Mark Solarz

Departmental News

Faculty

Temple University Department of Orthopaedic Surgery and Sports Medicine

Chairman

Joseph Thoder, MD, *The John W. Lachman Professor*

Professors

William DeLong, MD
Pekka Mooar, MD
Ray Moyer, MD, *The Howard H. Steel Professor*
Joseph Torg, MD
F. Todd Wetzel, MD, *Vice Chairman*

Associate Professors

Easwaran Balasubramanian, MD
Saqib Rehman, MD
Bruce Vanett, MD
Albert Weiss, MD

Assistant Professors

Joseph Eremus, MD
Christopher Haydel, MD
Eric Kropf, MD
Matthew Lorei, MD
Stanley Michael, MD
Alyssa Schaffer, MD
J. Milo Sewards, MD

Adjunct Faculty — Philadelphia Shriners Hospital

Randal Betz, MD, *Chief of Staff*
Philip Alburger, MD
Patrick Cahill, MD
Richard Davidson, MD
Corinna Franklin, MD
Scott Kozin, MD
G. Dean MacEwen, MD
Howard Steel, MD, *Emeritus Chief of Staff*
Joshua Pahys, MD
Amer Samdani, MD
William Schrantz, MD
Harold van Bosse, MD
Daniel Zlotolow, MD

Adjunct Faculty — Abington Memorial Hospital

Andrew Star, MD, *Chief of Orthopaedics*
Shyam Brahmabhatt, MD
David Craft, MD
Matthew Craig, MD
Greg Galant, MD
Michael Gratch, MD
Victor Hsu, MD
David Junkin, Sr., MD
Moody Kwok, MD
Guy Lee, MD
Thomas Peff, MD
T. Robert Takei, MD
Jeffrey Vakil, MD

Adjunct Faculty — St. Christopher's Hospital for Children

Peter Pizzutillo, MD, *Chief of Orthopaedics*
Kiersten Arthur, MD
Alison Gattuso, DO
Martin Herman, MD
Michael Kwon, MD
Juan Realyvasquez, MD
Joseph Rosenblatt, DO
Shannon Safier, MD
Michael Wolf, MD

Temple University Hospital
Department of Orthopaedic Surgery and Sports Medicine
Faculty 2012–2013

Joseph Thoder, MD
John W. Lachman Professor
Chairman
Hand & Upper Extremity
General Orthopaedics

Eswarian Balasubramanian, MD
Joint Reconstruction
General Orthopaedics

William DeLong, MD
Orthopaedic Trauma
Sports Medicine
General Orthopaedics

Joseph Eremus, MD
Foot and Ankle
General Orthopaedics

Christopher Haydel, MD
Orthopaedic Trauma
General Orthopaedics

Eric Kropf, MD
Sports Medicine
General Orthopaedics

Paul Lento, MD
Physical Medicine
and Rehabilitation

Matthew Lorei, MD
Joint Reconstruction
General Orthopaedics

Stanley Michael, MD
Sports Medicine
Joint Reconstruction
General Orthopaedics

Pekka Mooar, MD
Sports Medicine
Joint Reconstruction
General Orthopaedics

Ray Moyer, MD
Howard Steel Professor
Sports Medicine

Saqib Rehman, MD
Orthopaedic Trauma
General Orthopaedics

Alyssa Schaffer, MD
Hand Surgery

J. Milo Sewards, MD
Sports Medicine

Joseph Torg, MD
Sports Medicine

Bruce Vanett, MD
General Orthopaedics

Albert Weiss, MD
Hand & Upper Extremity
General Orthopaedics

F. Todd Wetzel, MD
Vice-Chairman
Spine Surgery

Orthopaedic Surgery
& Sports Medicine
Temple University Health System

Temple University Hospital
Department of Orthopaedic Surgery and Sports Medicine
House Staff 2012–2013

Emmanuel Atiemo, MD
PGY-5

Katharine Criner, MD
PGY-5

Joseph Dwyer, MD
PGY-5

Matthew Kleiner, MD
PGY-5

Scott Barbash, MD
PGY-4

Richard Han, MD
PGY-4

Emeka Nwodim, MD
PGY-4

Samuel Popinchalk, MD
PGY-4

Stephen Refsland, MD
PGY-3

Craig Steiner, MD
PGY-3

Rick Tosti, MD
PGY-3

Justin Iorio, MD
PGY-3

Rupam Das, MD
PGY-2

Colin Mansfield, MD
PGY-2

Kaziemierz Komparda, MD
PGY-2

Mark Solarz, MD
PGY-2

Dustin Greenhill, MD
PGY-1

James Lachman, MD
PGY-1

Anastassia Persidsky, MD
PGY-1

Ariana Trionfo, MD
PGY-1

Temple University Department of Orthopaedics — Publications by Faculty 2012–2013

Podium/Poster Presentations

2013

Padlakar M, McGoverin C, Barbash S, Kropf EJ, Pleshko N. Differentiation of ligament and tendon with near infrared spectroscopy. *ORS Annual Meeting,* San Antonio, Texas, January 26–29, 2013 (poster).

Whitaker JJ, Williamson C, Fowler JR, Kleiner MT, Haines C, Herman MJ. The Etiology of Childhood Limp Presenting to a Tertiary Care Pediatric Emergency Department: Risk Factors of Hospital Admission. *AAOS Annual Meeting,* Chicago, IL, March 18–23, 2013 (poster).

Steiner C, Richmond J, Solarz M, Kropf EJ. Access to care following acute anterior cruciate ligament injury: 2 year evaluation at a single urban center. *AANA Annual Meeting,* San Antonio, Texas, April 25–27, 2013 (e-poster).

2012

Mascarenhas R, Kropf EJ, Irrgang JJ, Chu CR, MacDonald PB, Harner CD. Inter-rater reliability in the grading of articular cartilage lesions of the knee: A comparison between arthroscopic and magnetic resonance grading. *AANA Annual Meeting,* Orlando, FL, May 17, 2012 (podium).

Mascarenhas R, Kropf EJ, Irrgang JJ, Chu CR, MacDonald PB, Harner CD. Arthroscopic and magnetic resonance imaging of articular cartilage lesions of the knee: Inter-rater and reliability between modalities. *Canadian Orthopaedic Association 67th Annual Meeting,* Ottawa, ON, Canada, June 8, 2012 (podium).

Han R, Mullen J, Ali S, Kropf EJ. Radiographic, CT and MRI Evaluation of Glenohumeral Bone Defects in Recurrent Shoulder Instability: Inter-observer Reliability and Agreement Between Modalities. *AANA Annual Meeting,* Orlando, FL May 17–19, 2012 (e-poster).

Duncan I, Kleiner M, Atiemo E, Michael S. Kropf EJ, Sewards JM. Is lateral decubitus position better than beach chair at providing visualization of the posterior labrum of the shoulder? *AANA Annual Meeting,* Orlando, FL, May 17–19 2012 (e-poster).

Tosti R, Fowler JR, Dwyer J, Gaughan JP, Ilyas AM, Thoder JJ. Is antibiotic prophylaxis necessary in clean soft tissue hand surgery? *American Academy of Orthopaedic Surgeons Annual Meeting,* February 7–11, 2012: San Francisco, CA.

Fowler JR, Perkins TA, Buttarro BA, Truant AL, Torg JS. Bacteria adhere less to barbed monofilament than other suture types in a contaminated wound model. *Orthopaedic Research and Education Foundations (OREF) Orthopaedic Research Society (ORS) Resident Research Competition – Philadelphia Region,* June 8–9, 2012: Philadelphia, PA.

First Place Winner, Podium Presentation

Torg JS, Boden BB, Hirsch H, Fowler JR, Gaughan JP, Comstock D, Tiernery R. Athletic Induced mTBI and Catastrophic Intracranial Injuries: Helmet Efficacy and Predisposing Profiles. *American Academy of Orthopaedic Surgeons Annual Meeting,* February 7–11, 2012: San Francisco, CA.

Publications in Peer Reviewed Journals

2013

Kropf EJ, Shen W, van Eck C, Musahl V, Irrgang JJ, Fu FH. ACL-PCL and intercondylar notch impingement: Magnetic Resonance Imaging of native and double-bundle ACL-reconstructed knees. *Knee Surg Sports Trauma* 2013 Mar;21(3):720–5.

2012

Mascarenhas R, Tranovich MJ, Kropf EJ, Fu FH, Harner CD. Bone-patellar tendon-bone autograft vs hamstring autograft anterior cruciate ligament reconstruction in the young athlete: A retrospective matched analysis with 2–10 year follow-up. *Knee Surg Sports Trauma* 2012 Aug;20(8): 1520–7.

Auerbach AD, Rehman S, Kleiner MT. Selective transcatheter arterial embolization of the internal iliac artery does not cause gluteal necrosis in pelvic trauma patients. *J Ortho Trauma.* 2012 May;26(5):290–5.

Fowler JR, Criner K, Craig MR. Prophylactic Intramedullary Fixation for Bisphosphonate-related Subtrochanteric Stress Fracture. *Orthopaedics* 2012 Jun 1;35(6):e954–7.

Fowler JR, Kleiner MT, Das R, Gaughan JP, Rehman S. Assisted closure of fasciotomy wounds: A descriptive series and caution in patients with vascular injury. *Bone and Joint Research* 2012 March;1(3):31–35.

Fowler JR, Craig MR. Association of low energy femoral shaft fractures with bisphosphonate use. *Orthopaedics* 2012 Jan;35(1):20.

Fowler JR, Ogrich L, Evangelista P, Schaffer AA. Assessing injection techniques in the treatment of trigger finger. *Modern Plastic Surgery* 2012 Oct;2(4):83–86. doi: 10.4236/mps.2012.24020.

Piposar J, Fowler JR, Gaughan JP, Rehman S. Race may not effect outcomes in operatively treated tibia fractures. *Clin Orthop Relat Res* 2012 May;470(5):1513–7.

Rehman S, Salari N, Codjoe P, Rehman M, Gaughan J. Gunshot femoral fractures with vascular injury: A retrospective analysis. *Orthop Surg* 2012 Aug;4(3):166–71.

Tosti R, Fowler JR, Dwyer J, Gaughan JP, Ilyas AM, Thoder JJ. Is antibiotic prophylaxis necessary in clean soft tissue hand surgery? *Orthopaedics* 2012 Jun;35(6):e829–833.

Textbook

Ilyas AM, Rehman S, eds. *Contemporary Surgical Management of Fractures and Complications, Volumes 1 and 2.* Jaypee Med. Publishing, 2013.

Book Chapters/ePublications

Rehman S, Criner K. "Tibial shaft fractures." In Ilyas AM, Rehman S, eds., *Contemporary Surgical Management of Fractures and Complications, Volumes 1 and 2.* Jaypee Med. Publishing, 2013.

Ilyas AM, Rehman S. "Distal humerus fractures." In Ilyas AM, Rehman S, eds., *Contemporary Surgical Management of Fractures and Complications, Volumes 1 and 2.* Jaypee Med. Publishing, 2013.

Manthe M, Suk M, Rehman S. "Distal tibia fractures." In Ilyas AM, Rehman S, eds., *Contemporary Surgical Management of Fractures and Complications, Volumes 1 and 2.* Jaypee Med. Publishing, 2013.

Haydel C, Rehman S. "Femoral neck fractures." In Ilyas AM, Rehman S, eds., *Contemporary Surgical Management of Fractures and Complications, Volumes 1 and 2.* Jaypee Med. Publishing, 2013.

Mellon M, DeLong W, Rehman S. "Distal femur fractures." In Ilyas AM, Rehman S, eds., *Contemporary Surgical Management of Fractures and Complications, Volumes 1 and 2.* Jaypee Med. Publishing, 2013.

Kleiner M, Kropf EJ. *Osteotomy for Knee Osteoarthritis — A Lost Art?* Orthopedics Hyperguide http://www.ortho.hyperguides.com/index.php?option=com_content&view=article&id=2336. January 2013, Vindico Medical Education Publisher.

Fowler JR, Thoder JJ. "Radial Head Fractures and Elbow Dislocations." In *Contemporary Surgical Management of Fractures and Complications.* Ilyas AM, Rehman S. Jaypee Medical Publishers New Delhi, India. April 2013.

Tosti R, Sheikh E, Ilyas AM. "Humeral Shaft Fractures." In Ilyas AM, Rehman S, eds., *Contemporary Surgical Management of Fractures and Complications.* Jaypee Medical Publishers, New Delhi, India, April 2013.

Kleiner M, Kropf EJ. "Patellofemoral Instability: Evaluation and Management," Chapter 10, pp 195–209. *The Knee: Current Concepts in Kinematics, Injury Types, and Treatment Options.* Nova Science Publishers Inc. August 2012, Hauppauge, New York.

Fowler JR, Guille J. "The Limping Child." In Elzouki AY, ed., *Textbook of Clinical Pediatrics.* Second Edition, Volume IV. Section 25 Pediatric Orthopaedics 2013;(405):3909–3916.

Wang JH, Kropf EJ, Fu FH. Double Bundle ACL Reconstruction. In Ryu RK, ed., *AANA Advanced Knee Arthroscopy.* 2010.

Kropf EJ, Haner CD. "Meniscus Root Repair." In Fu FH, ed., *Masters Techniques in Sports Medicine.* 2010.

Wong AK, Kropf EJ, Fu FH. "Anterior Cruciate Ligament." In Ranawat A, Kelly B, eds., *Musculoskeletal Examination of the Hip and Knee: Making the Complex Simple.* 2010.

Mascarenhas R, Kropf EJ, Harner CD. "Ligamentous Injuries of the Knee." In Sivananthan S, Miller MD, Sherry E, Warnke PH, eds., *Mercer's Textbook of Orthopaedic and Trauma Surgery.* 10th Edition. London, UK, 2009.

Torg, JS. "Cervical Spine Problems in the Adult Athlete in Orthopedic Sports Medicine, 3rd Edition." DeLee and Drez, eds. WB Saunders Co., Philadelphia, pp 665–700, 2009.

Wetzel FT. "Image Guided Therapy and Its Relationship to Conventional Surgical Management." In Mathis JM, Golovac S, eds., *Image-Guided Spine Interventions, 2nd Edition.* New York: Springer Science+ Business Media, 2009, pp 267–289.

Wetzel FT, Saulino ML. "Surgery for Chronic Pain." In Herkowitz H, Garfin S, Eismont FJ, Bell GR, eds., *Rothman-Simeone The Spine, Sixth Edition.* Philadelphia: Saunder Elesevier, 2009 (in press).

Grand Rounds 2012–2013

August 15	Kurosh Darvish, PhD: "Introduction to Spinal Biomechanics" Katharine Criner, MD: "The Relevance of Biomechanical Studies to Clinical Orthopaedic Practice"
September 15	Hassan Mir, MD: "Culturally Competent Care" Samuel Popinchalk, MD: "Complications with Subtrochanteric Femur Fracture Management"
October 17	Peter Pizzutillo, MD: "Developmental Dysplasia of the Hip" Scott Barbash, MD: "Complications with Management of Periarticular Fractures in the Pediatric Knee"
November 3	Andrew Star, MD: "Is There Really Such a Thing as Minimally Invasive Joint Replacement?" Richard Han, MD: "Vascular Complications in Total Knee Replacements"
November 21	Harold van Bosse, MD: "An Orthopaedist's Algorithm for Treatment of the Arthrogrypotic Child" Matthew Kleiner, MD: "Proximal Femoral Focal Deficiency"
December 12	Christopher Haydel, MD: "Staying Out of Trouble with Tibial Plateau Fractures" Emeka Nwodim, MD: "Proximal Tibia Fractures in Children and Adolescents"
January 16	F. Todd Wetzel, MD: "Conflicts of Interest" Stephen Refsland, MD: "Current Legal and Ethical Issues in Sports Orthopaedics"
January 19	Paul Lin, MD: "Pars Defect Repair" Joe Dwyer, MD: "Spondylolysis and Spondylolisthesis"
February 13	Mohit Bhandari, MD, PhD: "Think Big" Emmanuel Atiemo, MD: "Current Evidence with Intertrochanteric Hip Fracture Management"
March 9	Keith Wapner, MD: "Management of Hallux Valgus Deformity in the Adult" Richard Tosti, MD: "Stress Fractures of the Tarsal Navicular and Fifth Metatarsal"
March 27	Peter Lelkes, PhD: "Smart Biomaterials for Orthopaedic Applications" Justin Iorio, MD: "Methods to Minimize Blood Loss in Pediatric Spine Deformity Surgery"

Dr. Rehman and Dr. Bhandari


Dr. Torg and Dr. Wapner

Instructions to Authors

Editorial Philosophy

The purpose of the *Temple University Journal of Orthopaedic Surgery & Sports Medicine (TUJOSM)* is to publish clinical and basic science research performed by all departments of Temple University that relate to orthopaedic surgery and sports medicine. As such, *TUJOSM* will consider for publication any original clinical or basic science research, review article, case report, and technical or clinical tips. All clinical studies, including retrospective reviews, require IRB approval.

Editorial Review Process

All submissions will be sent to select members of our peer review board for formal review.

Manuscript Requirements

Manuscripts are not to exceed 15 double spaced type-written pages and/or 5,000 words (minus figures/tables/pictures). The manuscript should contain the following elements: Title page, Abstract, Body, References, and Tables/Legends. Pages should be numbered consecutively starting from the title page.

(1) Title Page — The first page, should contain the article's title, authors and degrees, institutional affiliations, conflict of interest statement, and contact information of the corresponding author (name, address, fax, and email address).

(2) Abstract — The second page, should be a one-paragraph abstract less than 200 words concisely stating the objective, methods, results, and conclusion of the article.

(3) Body — Should be divided into, if applicable, Introduction, Materials & Methods, Results, Discussion, and Acknowledgements. Tables and figures (in JPEG format) with their headings/captions should be listed consecutively on separate pages at the end of the body, not continuous within the text.

(4) References — Should be listed following the format utilized by *JBJS.* For example: Smith, JH, Doe, JD. Fixation of unstable intertrochanteric femur fractures. *J Bone Joint Surg Am.* 2002;84:3553–58.

Submissions

All submissions are now digital. Please submit the manuscript in a Microsoft Word document to templejournal@gmail.com.

Disclaimer: **This journal contains manuscripts that are considered interpersonal communications and extended abstracts and not formalized papers unless otherwise noted.**

The ATTUNE™ Knee System is the largest-ever research and development project from DePuy Synthes Joint Reconstruction. Novel testing protocols and methods were used during development. Each aspect of knee replacement design and surgical process was evaluated. And it was this rigorous process that has produced patented technologies to address the patient need for stability and freedom of movement.

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