QUANTUM MAGNETIC RESONANCE(QMR) THERAPY AS AN EFFECTIVE TREATMENT FOR OSTEOARTHRITIS: RESULTS OF PHASE II STUDY

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Abstract

Objectives: To study the effects of quantum magnetic resonance (QMR) beams on clinical and functional parameters and cartilage thickness of osteoarthritic knee joints.

Methods: One hundred and ninety five patients with bilateral osteoarthritis (OA) of the knees were assessed on the basis of the internationally recognized Knee Society clinical rating system, and the scores were computed prior to treatment, after 21 days of QMR therapy, and at three months. In addition, MRI of the knees was done using standard protocol, before the treatment and at three months, to measure objective changes in cartilage thickness in the treated knee joints.

Results: The results of this prospective, non-randomized, phase II study showed statistically highly significant improvement in pain scores, total knee scores, total functional scores and the range of motion, immediately after the treatment vis-à-vis pre-treatment values, and this improvement persisted when evaluation was repeated at three months. There was also a significant increase in cartilage thickness at three months, from 0.64mm (±0.02) pre-treatment to 0.88 mm (±0.07) in left knee, and 0.65mm (±0.02) to 0.89mm (±0.05) in the right knee joint ($p<0.001$).

Conclusion: Therapeutic exposure to quantum magnetic resonance beams is effective in ameliorating the signs and symptoms of OA, and inducing regenerative activity in the chondrocytes as evidenced by an increase in the cartilage thickness. QMR therapy could be an effective treatment modality for osteoarthritis, with a potential to reverse the disease process.

Introduction

Osteoarthritis (OA) is the progressive destruction of the articular cartilage, generally manifested in weight bearing joints and fingers. OA has been defined as "a group of overlapping distinct diseases which may have different etiologies, but with similar biologic, morphologic and clinical outcomes. The disease processes not only affect the articular cartilage, but involve the entire joint, including the subchondral bone, ligament, capsule, synovial membrane, and periarticular muscles. Ultimately, the articular cartilage degenerates with fibrillation, fissures, ulceration and full thickness loss of the joint surface" [1].OA is responsible for significant pain and disability, and was reported by the World Health Organization to be the fourth leading cause of years lost due to disability (YLD) globally, in the year 2000 [2]. Despite the significant burden of the disease, a lack of complete understanding of the underlying disease process has been reflected in the existing therapies for OA that at best mitigate the symptoms of the condition [3].

Mild to moderate OA has been treated with activity modification, physiotherapy, walking aids, analgesics, non-steroidal anti-inflammatory drugs (NSAIDs) and intra-articular steroid injections, while surgical interventions such as joint lavage, arthroscopic debridement, osteotomy, arthrodesis and joint replacement are indicated in severe OA to bring relief to the patients [4]. However, these therapies are not known to effectively modify or reverse the OA disease process [5,6].

With better understanding of the pathophysiology of osteoarthritis, treatments that modify the natural course of the disease or even reverse the disease process and regenerate the damaged cartilage are being developed. Disease-modifying osteoarthritis drugs (DMOADs) are already being used for their chondroprotective effects that alter the course of the disease, consequently relieving the symptoms of OA to varying extents [7]. Furthermore, the rapidly emerging fields of gene therapy, stem cell therapy [8] and cartilage tissue engineering techniques [9] hold promise as potential methods for cartilage repair and regeneration. However, these therapies are considered to be expensive, and are in early stages of studies or development [9,10].

The interaction between conventional electromagnetic (EM) fields and biological systems has been a subject of intense study and generated tremendous interest in the scientific community [11,12]. Experimental studies have indicated the possibility of modulating biological functions and structures in a controlled way through electromagnetic beams in the sub-radio and near-radio frequencies. These EM beams can be easily modulated and hence used to transmit specific information at molecular levels. Further, the detection and measurement of endogenous EM resonance in living organisms and their components can be an indicator of biological functions.

There are three types of EM effects on living matter: ionizing, thermal and non-thermal effects. Thermal effects increase entropic disorder in the target, until effects of ionization develop at certain frequencies and power levels. The non-thermal effects, on the other hand, can transmit information to the target producing order in the bio-structures involved. This principle is used in diagnostic magnetic resonance imaging (MRI). These non-thermal effects are like the tissue response to radio frequency pulse during magnetic resonance imaging, and are in line with the theories of the coherence of condensed matter [12,13]. The information content of a quantum EM beam is highly specific and depends on the dosimetry, which includes the waveforms, the string of waves, and the time sequence of modulation of the beam. It has been found that these EM beams, at specific configurations and time sequence patterns could induce very specific biological responses in the exposed bio-structures similar to pharmaceutical products [12] Studies carried out by several authors suggest the possibility of leveraging the biological effects of EM beams, including electroporation of the cell membrane, for therapeutic advantage [14-18]. Pulsed electromagnetic fields have been employed to produce desired therapeutic effects in disease conditions including osteoarthritis [15, 19, 20].

Technology has made it possible to deliver dosimetrically modulated Quantum Magnetic Resonance (QMR) beams to the target tissues. The beams are delivered by a multi-processor controlled device (QMR machine) that generates precise high intensity quantum magnetic resonance beams from specially designed magnetic field generatos(MFG), which produce high instantaneous magnetic fields. At the same time, the antennae at the core of the MFG generate radio frequency (RF) pulses in the near field. These MFGs are focused on the target tissue with the help of laser guides. The QMR beams are delivered in the sub-radio and near-radio frequency band, and work on the principle of altering cell membrane potential and "selectively jamming" the "command and control" of the target tissue cells by modifying the proton spin inside and outside the cells. These beams can be precisely modulated to alter the cell dynamics by interfering with gene messages that would aid in regeneration or degeneration of the target cells. The regenerative effects are leveraged in OA therapy to stimulate cartilage growth [13], while the beams can also be modulated to destroy malignant cells in cancer therapy [21].

Bones and cartilage are dynamic tissues that are being built up and broken down under the influence of various metabolic and physical factors. When these structures are subjected to compression or tension a piezoelectric signal is generated, which acts as a major stimulus for bone and cartilage formation. The QMR beams are designed to characterize and reproduce the piezoelectric signals, which suitably alter the membrane potential to favor the synthesis of proteins that facilitate cell division in the otherwise “hibernating chondrocytes”. An alteration of QMR spin in the hydrogen atoms generates streaming voltage potential due to forced movement of protons in the extracellular matrix (ECM), which initiates the regenerative activity [13].

In a previous study, Vasishta, et al. (2004) have demonstrated that daily therapy with QMR for 21 days reduces pain and increases the joint mobility, stability and power of the knee joint. Further, no deterioration was observed in the knee scores or pain status of the osteoarthritic patients during follow up after 30-days. These effects were thought to be caused by stimulation and subsequent regeneration of cartilage as a result of QMR therapy [13]. There was no significant change in body temperature and other vital physiological parameters during the treatment and none of the patients experienced claustrophobia during the procedure. No adverse effects were reported during follow up.

In the light of positive results of the phase I study, the present phase II study was designed with the objective of observing the effect of QMR therapy on various knee parameters and cartilage thickness (CT).

Materials and Methods

Study Setting

A total of 195 patients with clinically and radiologically confirmed osteoarthritis of the knee joint were enrolled into the study on a first-come, first-served basis, from among the 2000 trial volunteers who registered at the Department of Radiology, Institute of Aerospace Medicine (IAM). The study was conducted at the IAM, Indian Air Force, Bangalore, a premier teaching and research center. The study was conducted from July 2004 to June 2006 after approval by the ethics committee at the IAM. A written informed consent was obtained from all the patients and appropriate counseling was provided prior to all interventions.

QMR Machine

Quantum magnetic resonance beams were delivered by a computer controlled device that generates precise, high intensity QMR beams from specially designed magnetic field generators(MFG) that are then focused on the target tissue.

Study Patients: Inclusion and Exclusion Criteria

Study subjects were recruited from among the interested trial volunteers who reported to the Department of Radiology at the Institute of Aerospace Medicine. The subjects were counseled verbally, and further educated through presentations and dummy demonstration of the procedure. Written informed consent was obtained from consenting subjects who were subsequently interviewed and examined clinically. Patients with confirmed clinical and radiological evidence validating the diagnosis of osteoarthritis of the knee were enrolled in the study. Patients with surgical implants, pacemakers, or a history of cancer were excluded from the study.

Assessment of the Knee Joint

Assessment of the knee joint was done using both objective and subjective parameters. Objective data were obtained from X-rays, ultrasonography, and MRI. The condition of the knee joints was first assessed by X-Ray and ultrasound examination at the Department of Radiology, IAM.

Ultrasonography was used to detect the presence of effusion in the knee joint, plan the dosage and map the region of interest to aid precise focusing of QMR beams. Measurement of physical parameters, such as height, weight, length of tibia, alignment, and stability, were carried out apart from goniometric measurements. Goniometric measurements included an evaluation of flexion, range of motion and extension lag, medial-lateral and anterior-posterior stability. Subjective parameters such as pain and other disabilities were assessed using the Knee Society clinical rating system [22].

Cartilage thickness was measured using MRI. The MRI parameters acquired were reproducible using conventional magnetic resonance scanner with field strength of 1.5 tesla. Cartilage thickness was calculated using a three-dimensional (3-D) co-ordinate transformation of tibial and femoral cartilage data. The MRI sequence used was Proton Density T2 weighted with fat-suppressed, gradient-echo sequences [23, 24]. The point selected for measurement of cartilage thickness was on the medial tibial condyle at the level of the tibial spine.

Pre-exposure clinical and subjective data were obtained from the subjects and recorded as per the internationally accepted Knee Society clinical rating system. According to the Knee Society rating system, pain (P) has a maximum score of 50 points for ‘no pain’, 25 points for maximum stability, and 25 points for maximum range of motion (ROM), with the total knee score (TKS) having a maximum score of 100. The total functional score (TFS) also has a maximum score of 100 when an individual can walk unlimited distances and walk up and down stairs without holding the railing [22].

All patients were treated as out-patients. Subjects’ knees were exposed to multi-frequency narrow focused quantum magnetic resonance using the QMR machine, everyday for 30 minutes, for 21 successive days. The affected joint (knee) was placed inside the QMR machine and the exposure characteristics for each knee, including the cartilage to bone gap, skin to cartilage distance, age, gender, height and weight, along with the name of the subject was fed into the computer, following which therapeutic exposure was carried out. After 21 exposures, the patients were re-assessed using TKS and TFS. Cartilage thickness was measured pre-treatment and post-treatment at 90 days using MRI. The cartilage thickness measurements were done randomly by different radiologists using the technique mentioned above, and not by the principal investigator, in order to avoid any potential bias. None of the imaging centers or the reporting radiologists had any interest in the study.

Safety

The subjects did not feel any pain or discomfort during the treatment. The vital parameters, including body temperature, were within normal range during the therapy and the patients did not experience claustrophobia. The QMR machine periodically measured dose parameters on the body surface of the subjects. The energy delivered during the therapy was well within the safety norms prescribed by the International Commission for Non-Ionizing Radiation Protection (Electronics and Radar Development Establishment, Ministry of Defense, Government of India, test report nos. EMR/EMI-EMC/TEST/R: 370,378,388). Delivered energy levels of various EM radiations are comparatively tabulated (Table 1).

Table 1 - Frequency, Wavelength and Energy Delivered by Therapeutic Radiations in the Electromagnetic Spectrum

Radiation	Frequency*	Wavelength*	Energy Delivered*
X-rays	1.7-3.6 x 1018	80-400 pM	30 – 150 KeV
Ultra Violet	7.5 x 1014	400 nM	3.1 eV
Infrared	4.3 x 1014	700 nM	1.8 eV
QMR	1 KHz – 100 MHz	6 – 60 M	20 – 200 meV

* p=pico, n=nano, M=Meter/Mega, eV=electron volt, K=kilo, m=milli, Hz=cycles per second

Statistical Analysis

The statistical analysis was carried out using SPSS version 10.0. For the purpose of statistical analysis, each knee was considered as one case, and a total of 390 cases were analyzed. Normality of the distribution was assessed using Kolmogorov-Smirnov test. The effect of QMR therapy was assessed and compared for right knee (195) and left knee (195) separately; and collectively in all cases (390), between pre and post-treatment periods. The treatment effects were measured as pain score, range of motion, total knee score, total functional score for both the knees pre-treatment, and post-treatment at 21days and at 90 days; and cartilage thickness was recorded pre-treatment and post-treatment at 90 days.

Analysis and comparison of the Knee Society score between the treatment periods, pre-treatment and post-treatment 21 days, and pre-treatment and post-treatment 90 days; and comparison of CT between pre-treatment and post-treatment 90 days, was done for both knees using paired Student's t-test. One-Way ANOVA and Tukey's post hoc tests were used for comparing the effect of treatment period on right and left knee separately. Two way ANOVA and post hoc tests were used for comparing the significance of the treatment of both knees when considered together. All the values are given as mean ± SEM (unless stated otherwise) and the value of $p<0.005$ was considered as statistically highly significant.

Results

Characteristics of Study Population

Amongst the study population, females comprised of 72.82% and males, 27.18% (Table 2). The mean age of the sample population was 64.23±0.69 yrs (ranging from 29-85 years).

Table 2 - Distribution of the Study Patients

Sex	Number	Percentage
Males	53	27.18
Females	142	72.82
Total	195	100

Pain

Pain scores are inversely proportional to the degree of pain. A zero score represents severe pain with restricted mobility. Most subjects showed improvement in pain after the therapy. Pain abated significantly after the fifth or sixth day of treatment in most cases, with a significant pain reduction in both the right and left knees at the completion of the QMR therapy.Out of 195 (left knee) cases, 50.53% had pain score of 0 at the start of treatment. Among them 29.25% improved to score 10 and 26.59% to score 20 after 21 days of treatment. At 90 days, 50.53% of these patients had pain score of 40.

Out of 195 cases (right knee), 51.59% had pain score of 0 at the start of treatment. After 21 days of treatment, 29.25% of them had pain score of 10 and 26.59% had pain score of 20. After 90 days, 50.53% of them improved to a score of 40. The mean pain scores for both right and left knees when considered individually, as well as together during the course of treatment are indicated in tables 3, 4 and 5, respectively. The mean pain score at the beginning of the treatment was 6.54 (±0.66) and 6.77 (±0.66) for the left and right knees, respectively. The mean pain score significantly improved to 18.92 (±0.87) and 19.15 (±0.87) after 21 days, and 28.77 (±0.95) and 28.83 (±0.97) after 90 days, for left and right knees, respectively.

Range of motion

The range of motion increased progressively in most subjects over the treatment period. The mean range of motion score for the knee joint increased significantly from 14.17 (±0.14) to 14.83 (±0.14) for the left knee; and 14.33 (±0.12) to 15.06 (±0.11) for the right knee after 21 days of treatment. After 90 days, the ROM scores for the left and right knees further improved to 16.17 (±0.51) and 16.35 (±0.51), respectively.

Out of 195 cases (left knee), 74.46% had ROM score of 15 at the start of treatment. After 21 days of treatment 76.59% of them had ROM score of 15. After 90 days 58.51% improved to ROM score of 16.

Out of 195 cases (right knee), 34.57% had ROM score of 15 at the start of treatment. After 21 days of treatment, 47.87% of them had ROM score of 16, and after 90 days, 63.82% had ROM score of 16.

Further, the effects of medial lateral (ML) and anterior posterior (AP) stability are also indicated. The mean ROM, ML and AP values for both right and left knees, when considered individually as well as together during the course of treatment, are indicated in tables 3, 4, and 5, respectively. There was no significant change in the AP values at all time intervals during the course of treatment. The mean medial lateral score of knee joint increased significantly from 6.28 (±0.18) to 7.08 (±0.20) for the left knee, and 6.15 (±0.18) to 7.03 (±0.20) for the right knee, after 21 days of treatment. After 90 days, the mean medial lateral scores for the left and right knees further improved to 9.87 (±0.57) and 9.90 (±0.58), respectively.

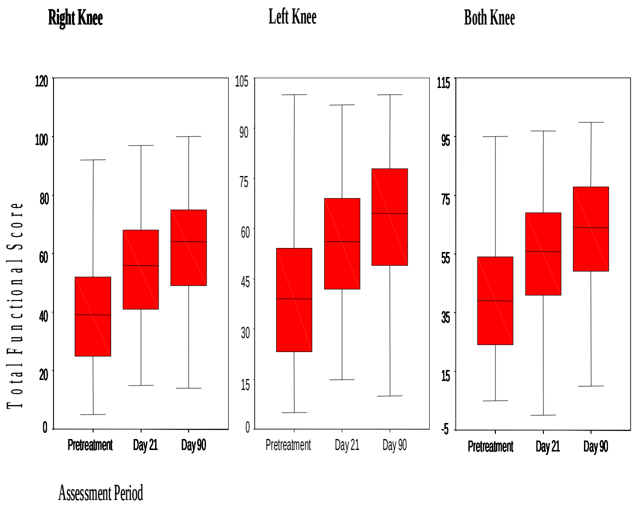
Total Functional Score

TFS improved significantly in all the subjects and they were able to walk comfortably after the therapy for considerable distances (Fig.1). The mean TFS values for both right and left knees, when considered individually as well as together during the course of treatment, are indicated in tables 3, 4, and 5, respectively.

The mean TFS for the right knees improved from 41.39 (±1.47) to 55.14 (±1.44) at 21 days, and to 60.74 (±1.66) at three months, while the scores for the left knee were 41.20 (±1.47) pre-treatment, 55.08 (±1.45) at 21 days and 61.19 (±1.67) at 90 days.

Out of 195 cases (left knee), 19.68% had functional score of 47.5 at the start of the treatment. After 21 days of treatment, 21.27% of them had a functional score of 57.5. At 90 days 12.23% of these patients improved to a total functional score of 70.

Out of 195 cases (right knee), 34.57% had functional score of 32.5 at the start of the treatment. After 21 days of treatment, 19.68% of them had functional score of 47.5, and at 90 days 12.76% had a functional score of 60.



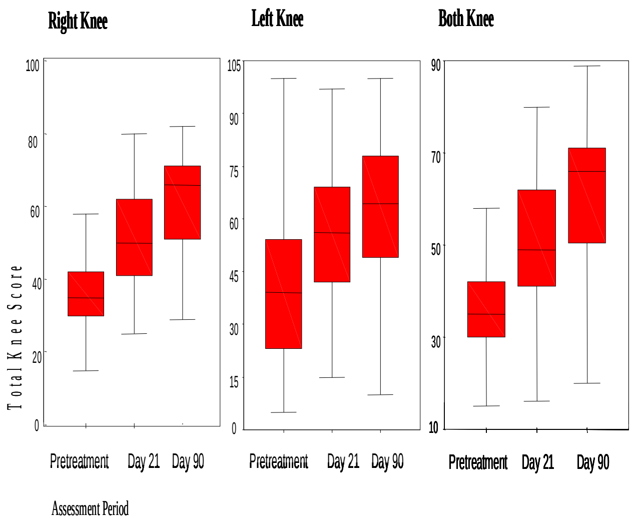
Total Knee Score

TKS improved significantly in all patients (Fig. 2). The mean TKS values for both right and left knees when considered individually as well as together during the course of treatment are indicated in tables 3, 4 and 5, respectively.

The mean total knee score for the right knee improved from 37.37 (±0.7) to 50.88 (±0.91) post-treatment 21 days and 59.85 (±1.28) at 90 days. The mean initial TKS for left knee was 37.11 (±0.74), and improved to 50.24 (±0.92) at 21 days and 59.93 (±1.29) at 90 days.

Out of 195 cases (left knee), 57.44% had total knee score of 32.5 at the start of treatment. After 21 days of treatment, 34.04% of them had total knee score of 47.5, and 23.40% had total knee score of 37.5. After 90 days, 29.78% had total knee score of 70.

Out of 195 cases (right knee), 57.44% had total knee score of 32.5 at the start of treatment. After 21 days of treatment, 34.04% of them had total knee score of 47.5. After 90 days, 28.72% had total knee score of 70.



Cartilage Thickness

There was a significant increase in cartilage thickness after QMR therapy (Fig. 3). The mean CT values for both right and left knees, when considered individually as well as together during the course of treatment, are indicated in tables 3, 4 and 5, respectively. The effect of the treatment can be seen objectively by cartilage thickness measurement on MRI. There was a significant improvement in the thickness of the cartilage. The mean thickness of cartilage increased from 0.64mm (±0.02) and 0.65mm (±0.02), to 0.88mm (±0.07) and 0.89mm (±0.05) in the left and right knee joints, respectively.

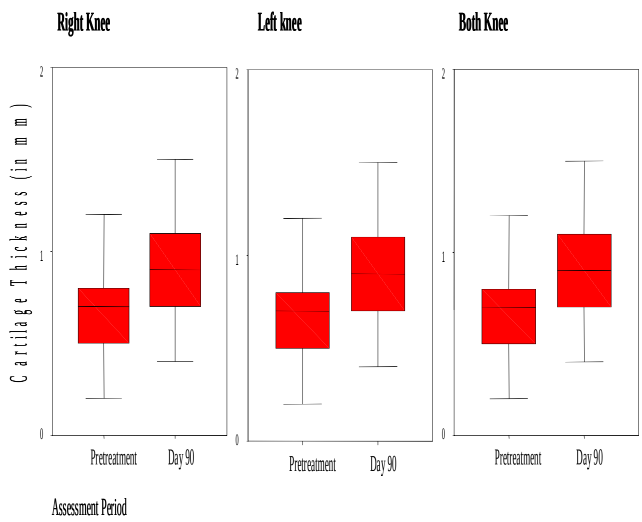


Table 3 - Effect of QMR Therapy on Various Parameters of Right Knee at Different Treatment Periods

Parameters		Pre-treatment	Post-treatment	
		0 days	21 days	90 days
		(Mean ± SEM)	(Mean ± SEM)	(Mean ± SEM)
Pain		6.77 ± 0.66	19.15 ± 0.87*	28.83 ± 0.97a
ROM	Total	14.33 ± 0.12	15.06 ± 0.11*	16.35 ± 0.51a
	ML	6.15 ± 0.18	7.03 ± 0.20*	9.90 ± 0.58a
	AP	10.00 ± 0.00	10.00 ± 0.00	11.10 ± 0.53
TFS		41.39 ± 1.47	55.14 ± 1.44*	60.74 ± 1.66a
TKS		37.37 ± 0.7	50.88 ± 0.91*	59.85 ± 1.28a
Cartilage Thickness (in mm)		0.65 ± 0.02	-------	0.89 ± 0.05a

Each value represents Mean ± SEM of 195 observations; * represents p<0.001 between pretreatment and post treatment (21 days); a represents p<0.001 between pretreatment and post treatment (90 days).

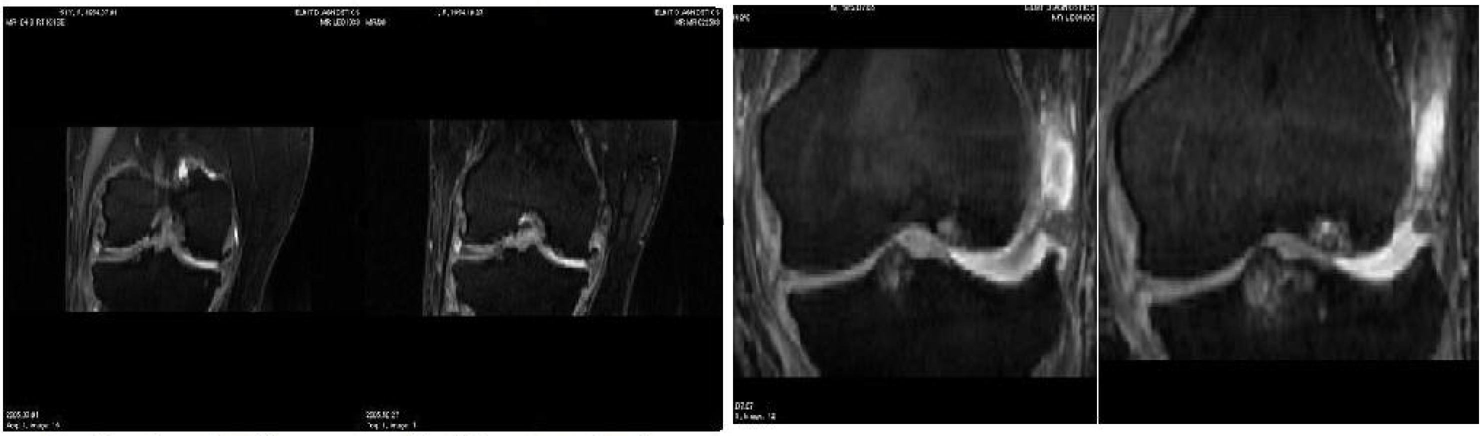
Table 4 - Effect of QMR Therapy on Various Parameters of Left Knee at Different Treatment Periods

Parameters		Pre-treatment	Post-treatment	
		0 days	21 days	90 days
		(Mean ± SEM)	(Mean ± SEM)	(Mean ± SEM)
Pain		6.54 ± 0.66	18.92 ± 0.87*	28.77 ± 0.95[a]
ROM	Total	14.17 ± 0.14	14.83 ± 0.14*	16.17 ± 0.51[a]
	ML	6.28 ± 0.18	7.08 ± 0.20*	9.87 ± 0.57[a]
	AP	10.00 ± 0.00	9.95 ± 0.05	11.24 ± 0.62
TFS		41.20 ± 1.47	55.08 ± 1.45*	61.19 ± 1.67[a]
TKS		37.11 ± 0.74	50.24 ± 0.92*	59.93 ± 1.29[a]
Cartilage Thickness (in mm)		0.64 ± 0.02	-------	0.88 ± 0.07[a]

Each value represents Mean ± SEM of 195 observations; * represents p<0.001 between pretreatment and post treatment (21 days); [a] represents p<0.001 between pretreatment and post treatment (90 days).

Table 5 - Effect of QMR Therapy on Various Parameters in Both-Knees at Different Treatment Periods			
Parameters	**Pre-treatment**	**Post-treatment**	
	0 days (Mean ± SEM)	**21 days(Mean ± SEM)**	**90 days (Mean ± SEM)**
Pain	**6.65 ± 0.46**	**19.04 ± 0.61***	**28.23 ± 0.65[a]**
ROM	**14.25 ± 0.09**	**14.94 ± 0.09***	**15.58 ± 0.07[a]**
ML	**6.22 ± 0.13**	**7.05 ± 0.14***	**8.67 ± 0.13[a]**
AP	**10.00 ± 0.00**	**9.97 ± 0.03**	**9.96 ± 0.29**
TFS	**41.29 ± 1.03**	**55.11 ± 1.02***	**63.86 ± 0.97[a]**
TKS	**37.24 ± 0.51**	**50.56 ± 0.65***	**62.53 ± 0.62[a]**
Cartilage Thickness (in mm)	**0.65 ± 0.02**	**-------**	**0.89± 0.01[a]**

Each value represents Mean ± SEM of 390 observations; * represents $p<0.001$ between pretreatment and post treatment (21 days); [a] represents $p<0.001$ between pretreatment and post treatment (90 days).



Pre Treatment Cartilage Thickness - 0.6mm | Post Treatment Cartilage Thickness - 0.9mm | Pre Treatment Cartlage Thickness - 0.6mm | Post Treatment Cartilage Thickness - 0.9mm

Discussion and Conclusion

Osteoarthritis is the most common joint disorder and the most common form of arthritis in humans. The integrity of the articular cartilage is maintained by numerous anabolic and catabolic factors that achieve equilibrium under normal conditions. Cartilage breakdown ensues when the equilibrium is disrupted either due to inability of the joint tissues to respond to the anabolic factors, or because of the excessive presence of catabolic factors. Therapies for OA, aimed at reversing the disease process, strive to prevent cartilage breakdown and aid in regeneration of chondrocytes, which manifests as an increase in cartilage volume and a radiographic reappearance of previously disappeared joint space [7].

The possibility of measuring cartilage thickness for quantitative assessment of osteoarthritis and response to OA therapy using MRI has been described recently [24-26]. The use of MRI for quantitative assessment in knee osteoarthritis evaluation is potentially superior to arthroscopy and fluoroscopy, as image acquisition using MRI is both non-invasive and non-radiant. Moreover, the MRI quantification system for measuring cartilage thickness is considered to be highly reliable. This technology enables the assessment of cartilage thickness variability in individuals over time, and is critical for the analysis of disease progression [23, 27]. MRI is also shown to be reliable in measuring cartilage surface topographies and detecting focal cartilage defects [28, 29]. MRI further helps in visualizing joint structures, such as cartilage, bone, synovium, ligaments and meniscus, and determining any morphological changes in them [30].

The earlier 'gold standard' for measuring cartilage thickness has been the radiographic method, which allows the measurement of the width of the narrowest joint-space. However, studies have suggested that radiography by itself is not a sensitive measure to assess progression of cartilage loss [31,32]. The use of MRI for measuring cartilage thickness in this study has aided the precise quantification of cartilage thickness and, hence the response to QMR therapy.

The results of the phase I study on the safety and efficacy of QMR therapy in 36 patients with OA indicated that QMR could stimulate the regeneration process in the chondrocytes, reduce pain, and increase mobility of the joint, thus reversing the negative cycle of disuse atrophy in the cartilage. The results of the present study on 195 patients (390 cases) have further provided quantitative evidence of a significant increase in the thickness of articular cartilage, substantiating the possibility of reversing the OA disease process. The study demonstrates that the use of QMR treatment for osteoarthritis significantly decreases pain, increases mobility, stability and power of the knee joint, and increases the cartilage thickness, establishing the efficacy of QMR in chondrogenesis.

No adverse effects, to the QMR therapy, were recorded during the course of the treatment or on follow-up at three months.

Therapeutic exposure of the knee cartilage to QMR is an effective method of treatment for OA. QMR therapy brings about a significant subjective and objective improvement in individuals suffering from OA, increasing their ability to lead a normal life. The results suggest that this non-surgical, non-invasive therapy is a landmark treatment for OA, potentially reversing the osteoarthritis disease process.

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Declaration of competing interests

During the period of research the author was full time Professor and Head of Department of Radiology at Institute of Aerospace Medicine and had no competing interest.

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