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IMPLANTS OF SMALL JOINTS IN HAND

Master's thesis

.

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ABSTRACT

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The wrist joints are often involved early in rheumatoid arthritis (RA). Small joints of wrist can be affected by hand arthritis leading to pain and deformity of the joints. Prosthetic development must take in to consideration range of motion, stability, fixation, ease of implantation, biocompatibility and soft tissue resconstruction. The metacarpophalangeal, interphalangeal and trapeziometacarpal joints each present different problems in the design of prostheses.This thesis focused on the arthritis of the basal joint of the thumb which most often affects middle-aged women. Basal joint is formed by carpometacarpal (CMC) joint and trapezium bone.

Several surgical techniques have been described for management of degenarative basal joint changes. These include excision of the trapezium alone, ligament reconstruction with or with out tendon interposition (LRTI) and trapezium resection, arthrodesis and multiple arthroplasty options using biologic and synthetic implants, including silastic prostheses, metal prostheses and allograft interpositions.

This study reviewed the literature related to the implants for trapezium bone failures in hand arthritis and also compared the techniques of joint arthroplasty for rheumatoid arthritis (RA). Trapezium bone is the main common area in osteoarthritis of the hand.

Researchers found out, successful and durable results with ligament reconstruction with or without tendon interposition.However pinch strength was not satisfactory due to shortening of the thumb by trapeziectomy. Joint arthroplasty can aid maintenance of the length of the thumb and provide greater pinch strength. Clinical assessments such as rate of motion (ROM), grip and pinch strength can evaluate the quality and durability of each technique. Several studies about silicone implants reported implant wear, synovitis and osteolysis. Metallic implants resulted in implant loosening and instability. Researchers found out a porous poly-L/D-lactide copolymer implant with an L: D monomer ratio of 96:4 (P (L/D) LA 96/4) resulted significiant strength and can be replaced with fibrous tissue in 2-3 years. Silicone implant is better at palmar stability compared to PLDLA (poly-L/D-lactide copolymer) implant, whereas lack of silicone synovitis and osteolysis are the advantages of the PLDLA implant. For achieving definite results, longer follow-ups are needed for synthetic allograft and PLDLA implants.

PREFACE

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I would like to dedicate this thesis to my family. The belief you have in me and the support you gave instilled the values and virtues that see me through on a daily basis.I would like to thank my grand father, Abbas Ali Sohrabi, and my grand mother, Manijheh Akbari Asbagh, who are always beside me with love and encouragement. I thank my father, Dr.Mohammad Barmaki, for encouraging me to embark on the project and for being a stalwart at all times. I thank my mother, Mrs. Minoo Sohrabi, for her tender, loving care and compassion. I thank my sister, Haleh Barmaki, for her kindness and warmth throughout the years. I know I am never going to be able to appreciate them enough.

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LIST OF SYMBOLS AND ABBRAVIATION

Abbreviation	Description
ADD	Adductor pollicis
ADL	Activities of daily living
AIA	Adjuvant induced arthritis
Al	Aluminium
APL	Abductor pollicis longus
APB	Abductor pollicis brevis
AOL	Anterior oblique ligament
BALLOT	Ballottement test
CMC	Carpometacarpal
CIA	Collagen induced arthritis
CSE	Conventional silicone elastomer
CT	Computed tomography
DIP	Distal interphalangeal joint
ECRL	Extensor carpi radialis longus
ECRB	Extensor carpi radialis brevis
ECU	Extensor carpi ulnaris
EPL	Extensor pollicis longus
FCR	Flexor carpi radialis
FCU	Flexor carpi ulnaris
FPB	Flexor pollicis brevis
FPL	Flexor pollicis longus
GJ	Graft Jacket
HA	Hydroxyapatite
HP	High performance
IP	Interphalangeal joint
K-wire	Kirschner wire
LRTI	Ligament Reconstructionn and Tendon Interposition
LRTI-PT	Ligament Reconstruction and Tendon Interposition with partail Trapeziectomy
LRTI-TT	Ligament Reconstruction and Tendon Interposition with total Trapeziectomy
MCP	Metacarpophalangeal
Nb	Niobium
OA	Osteoarthritis

Abbreviation	Description
PIP	Proximal interphalangeal joint
P(L/D)LA	Stereocopolymer of polylactide
RA	Rheumatoid arthritis
ROM	Range of motion
Sc	Scaphoid
SCW	Streptococcal cell wall arthritis model
SMD	Standard mean differences
SST	Scaphotrapeziotrapeziod
ST	Scaphoid shift test
STT	Scaphotrapezial
T	Trapezoid
TMC	Trapeziometacarpal
TiN	Titanium nitride
UHMWPE	Ultra-high molecular weight polyethylene
UMTDG	Ulnomeniscotriquetral dorsal glide test
2MC	Second metacarpal

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1. INTRODUCTION

Rheumatoid arthritis (RA) is one of the main inflammatory joint diseases which affects the small joints in hands and feets. Degenerative disease and arthritis of the joints can result in significant pain, stiffness, weakness and disability. These infections are more common in postmenopausal women [1].Carpometacarpal (CMC) joint, metacarpophalangeal joint (MCP), proximal interphalangeal joint (PIP) and distal interphalangeal joint (DIP) are affected joints of the hand in rheumatoid arthritis. Anti-inflammatory drugs and injections can provide relief for some patients, for those with severe disease, surgical treatments are needed [2].

The surgical treatments include trapeziectomy alone, trapeziectomy and ligament reconstruction with or with out tendon interposition, arthrodesis and methods of prosthetic implants arthroplasty. Ligament reconstruction with tendon interposition (LRTI) was considered as a proper method in rheumatoid arthritis. From several tendons which are located in the hand, FCR (Flexor carpi radialis) tendon is more suitable for harvesting in LRTI treatment. The main targets of the implant arthroplasty are to restore the hand motion, stability, durability and flexion, which are more relevant to design and material of the implant. This thesis aims at comparing the trapezium bone implants and techniques for assessment the better method that can improve the hand arthritis of patients [3].

The aim of this study is to focus more on the implants which can be applied instead of trapezium bone when it is affected by arthritis. Trapezium bone and carpometacarpal (CMC) joint are formed the basement of the thumb.Several types of implants were discussed in this area. Small joint arthroplasty using silicone elastomers have been used for more than 25 years for treatment of rheumatoid arthritis of the small joints of the hand, wrist and foot.These implants provide satisfactory results in range of motion (ROM) and pain relief. However the clinical benefits of silicone joint arthroplasty are often lost in long term follow-up and resulted infections in the body. For this reason other materials such as polymers, metals and synthetic allografts were also evaluated. For determining the improvement of arthroplasty treatments, clinical evaluations such as ROM, pinch and grip strength should be done and compare before and after the surgery [4].

2. BACKGROUND

Arthritis is a broad term used for a number of disorders, disease and issues related mainly to joints of the human body. There are mainly two types of arthritis of hand which are rheumatoid arthritis (RA) and osteoarthritis (OA).

2.1 Rheumatoid Arthritis (RA)

Rheumatoid arthritis (RA) is the most common type of the arthritis which can cause deformity and loss of function. It is an inflammatory disease that can affect on all joint surfaces. Wrist is the key joint in rheumatoid arthritis of the hand. Rheumatoid bone reduces the strength and stiffness compare to the normal bone. It was assumed that mainly synovial joints are affected. Synovial joints are the main joints of the body which have higher and complex motion compare to other joints. Common treatments of rheumatoid wrist are includeed splints, steroid injection and arthrodesis [5].

Arthrodesis treatment is done by removing the cartilage between two bones and attaching the bones by external fixation. A successful arthrodesis gives knee stability and decreases the pain. However the joint with an arthrodesis treatment is no longer flexible in the body. For this reason different kinds of artificial wrist implants (arthroplasty) should be used instead of this treatment.The aims for the development of joint implants are restoration of a functional range of motion, adequate stability, biologic compatibility and allowance for soft tissue reconstruction [5]. Recently, researchers find so many different implantable materials with various designs. The aim of this study is consider if wrist joint implantable biomaterials may have higher durability and better properties. Figure 2.1 shows the difference of the normal joint and RA affected joint.

a) b)

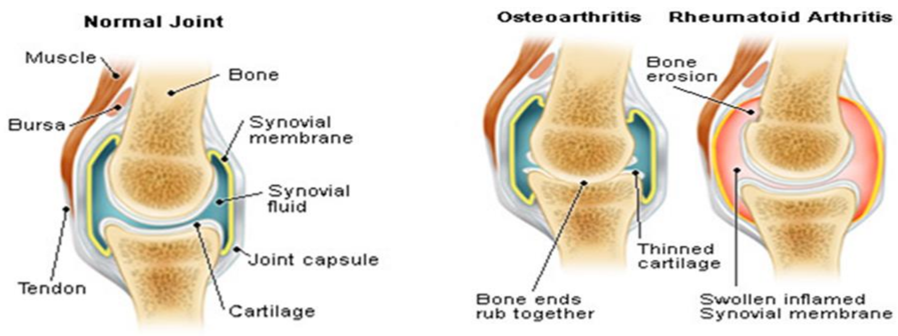


Figure 2.1*.a) Normal joint, b) Osteo arthiris and Rheumatoid Arthritis infections in a joint [6].*

2.2 Osteoarthritis (OA)

Osteoarhritis (OA) is the form of arthritis, which can be seen mostly in the thumb carpometacarpal joint and the interphalangeal (IP) joints. Osteoarthritis is results pain, swelling, stiffness and deformity. Mainly surgical treatment is applied on the patients with OA disease which is mostly observed in middle aged women [7]. The main differences of Osteoarthritis with RA can be seen table2.1.

Table2.1 *Difference between rheumatoid arthritis (RA) and osteoarthritis (OA)*

Rheumatoid arthritis (RA)	Osteoarthritis (OA)
1% of the population	10% of the population
Any age (Most common 40-60)	Increase with age (Usually begins after 50)
Involved in synovial membrane (thin membarane between joints)	Involved in cartilage

Osteoarthritis results from the breakdown of the tissue inside the joints, where as RA results from swelling in the joints. In RA pain occurs in joints on both sides of the body (both wrists, both ankles), whereas in OA pain was affected by only one joint. Figure 2.2 shows the steps of osteoarthritis in the bone [8; 9]. The main sides which are affected by OA and RA in a knee can be seen in figure 2.3.

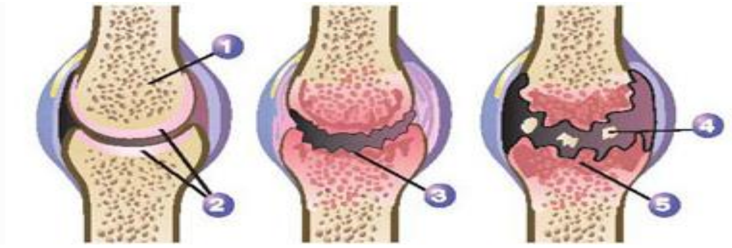


Figure 2.2 *Osteoarthritis; 1.Bone, 2.Cartilage, 3.Thining of the cartilage, 4.Cartilage particles, 5.Destruction of particles [10].*

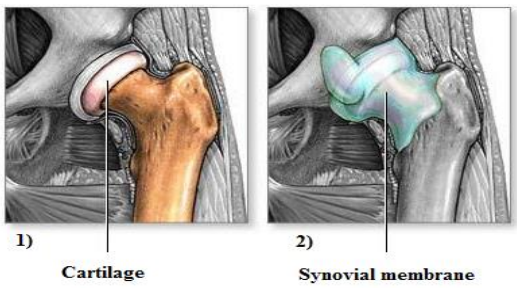


Figure2.3*. Bone arthritis 1) Cartilage affected by osteoarthritis 2) Synovial membrane affected by rheumatoid arthritis [11].*

2.3 Applied Material

The aim of the implant is to control space between the radius and the carpals and also wrist arrangement. For this reason different kinds of wrist implants by various kinds of materials were reported. Silicone rubber was the first biomaterial that used as an implant in the wrist joints. Silicon mainly causes synovitis, which is a serious complication of carpal or radiocarpal arthroplasty. The first symptom of the rheumatoid arthritis is synovitis. This infection has been observed in the synovial membrane and it's the first reaction of the RA in the joints. The stages of RA can be observed from figure 2.4.

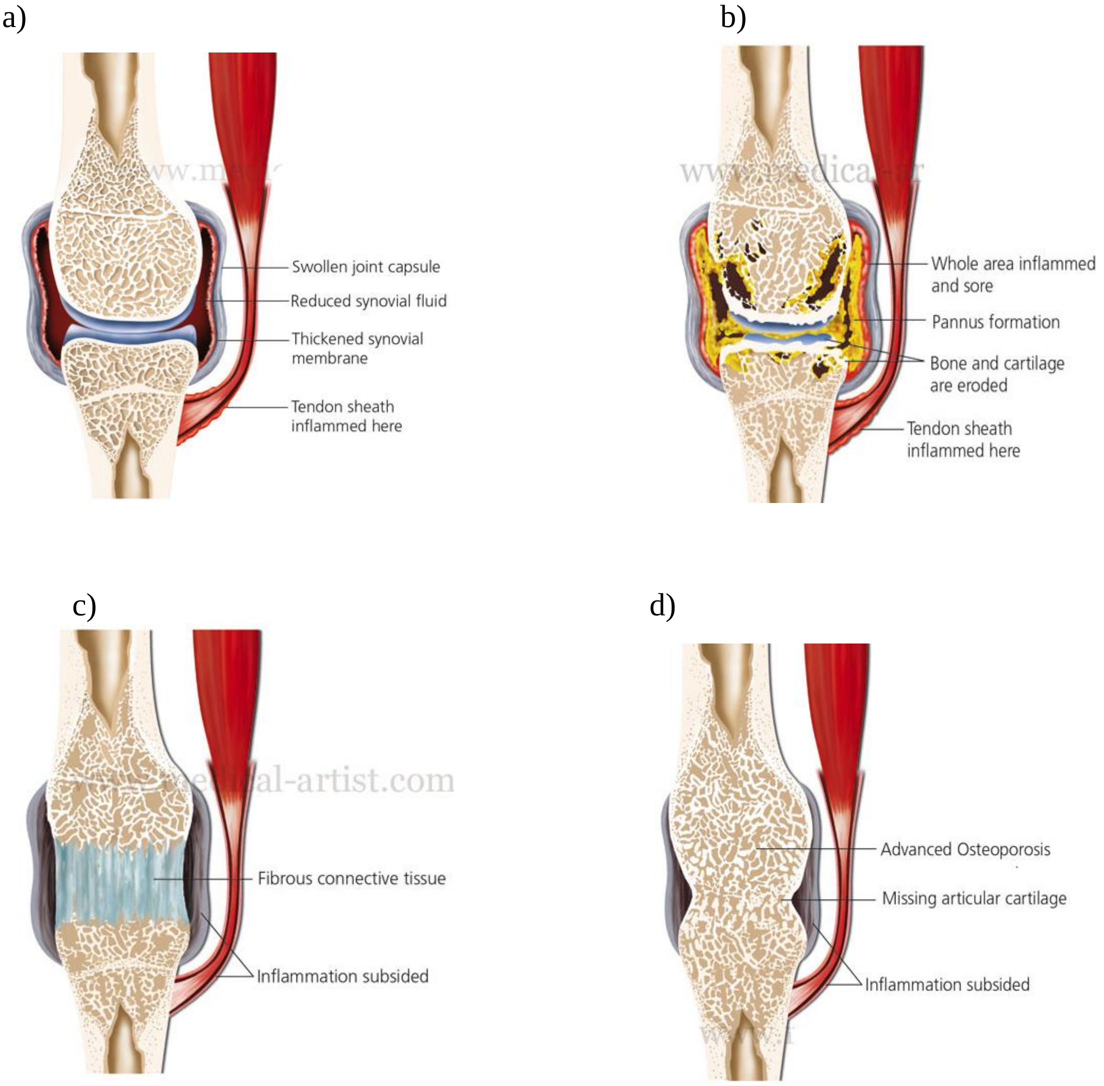


Figure 2.4. *Rheumatoid arthritis (RA) process; a) synovitis, b) pannus formation, c) fibrous Ankylosis, d) bony Ankylosis [12].*

Inflammation of the synovial membrane results a painful swelling. Pannus eventually destroys the bone and the cartilage. In the fibrous Ankylosis stage, the fibrous connective tissue resulted by the bone break down and in final stage, which is bony Ankolysis, the swelling and inflammation are decreased and the movement of the bone will be impossible.

Cobalt chrome alloy was another option for the wrist implant. This metal fits into the capitate and third metacarpal. The radial components of the wrist implant are also made from cobalt chrome alloy with a polyethylene surface. However in the clinical usage of these materials, the loosening of the metacarpal component and dislocation were resulted in cobalt chrome alloy. Another possible choice was a wrist implant with metal parts of Titanium alloy (Ti-6Al-7Nb). In this implant, Titanium nitride (TiN) was used as corrosion resistance and an ultra-high molecular weight polyethylene (UHMWPE) was applied between radial and carpal joints. The main disadvantage of this implant resulted from polyethylene which causes loosening of the metacarpal joints.
Titanium screws have good biocompatibility inside the bone. Recently the combination of polyurethane with silicone has been developed. This composition results beneficial biocompatibility, durability and strength to the implant.

2.3.1 Biomaterial Requirements

The main requirements of a biomaterial which can be used as implants in joint replacement are;

1. Mechanical properties: the major mechanical properties are hardness, tensile strength and modulus. A material with combination of high strength and same elasticity modulus with bone, prevents loosening of the implant. So it can be a good choice material for wrist joints.
2. Biocompatibility: Development of a material with high durability and non toxicity to the biological environment are the main requirements for a biomaterial.
3. High corrosion and wear resistance: The low wear and low corrosion resistance can cause failures such as loosening and non durability of the implant. Hence biomaterials with high corrosion and wear resistance should be use to increase the stability of the implant in the human system.
4. Osseointegration: osseointegration means a formation of direct interface between bone and implant without any soft tissue and formation of a new bone [13]. For this requirement the surface properties have very essential responsibility of making a good osseointegration. There are various reactions of the body to the implant; the best reaction is the formation of the new cells on the implant surface and propagation of bone cells. In this case, the implant was accepted by the body.The second stage is the formation of the soft tissue instead of bone which is not expected from osseointegration. The third case is the rejecting of the implant by human system.

Biomaterials

Silicon

Silicon implants have been used for replacement of the carpal bones, metacarpophalangeal (MCP) and wrist joints over than 25 years. Silicon rubber implant were used in carpal and radiocarpal joints, this material is a sufficient choice for ignoring the deformation and fibrilation during the implantation, however it can also cause failures such as silicon synovitis. Synovitis mainly appears in synovial membrane joint which is located between two bones; it is an inflammation of the synovial membrane. Silicon synovitis is a serious inflammation of carpal or radiocarpal arthroplasty. This infection occurred mainly in lunate carpal bone.

Silicon can decrease the pain, increase the hand functions and improve the durability and flexibility of wrist joints. This material is also chemically inert. Typically there are two types of silicone elastomers for joint implant; “the orginal conventional silicone elastomer (CSE) and a high performance (HP) elastomer” [14]. It was resulted that HP has higher strength than CSE and it can be also reduce the fracture in the implants. By applying silicone as implant material there can be observed some changes which can affect in a host tissue; these changes include:

1. Adsorption of macromolecules
2. Encapsulation
3. Wear debris
4. Modification of the implant [14].

The hydrophobic surface of the silicone adsorbs the different kinds of protein. By protein adsorption of silicone elastomer implant, the reaction to the primary inflammation of the host tissue can be increased. The encapsulation of the materials occure through the fibrous membrane. By encapsulation; the impant can not remain in the bone. Wear or corrosion which forms on material surface occur by motions between the surfaces. It affects the physical properties and structure of the implanted material. The amount of wear debris can be related to the effect of the load on the silicon implant and the duration of the implantation. Silicon elastomer can cause host reaction. One of the most important inflammatory reactions of Silicone implant is synovitis.
The main products which can result synovitis are; *prostaglandin -*E_2, *tumor necrosis factor -β, interleukin-1β* and *collagens*.These products mainly cause inflammation in synovial membrane. Bone joint synovial cavity and membrane of the bone joint can be observed from figure 2.5.

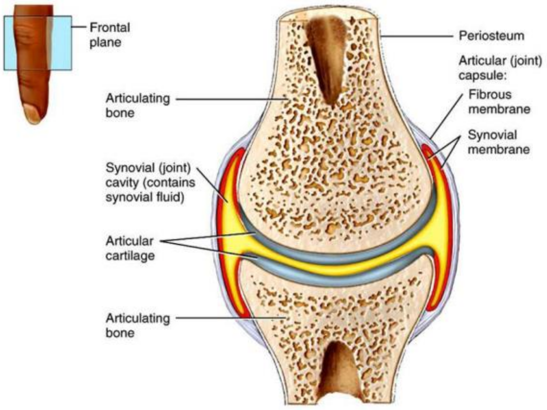


Figure 2.5. *Synovial joint [15].*

Silicon synovitis in clinical studies appears by pain, loss of motion and swelling. Figure 2.6 is schematic of silicon synovitis after silicone implantation.

Figure2.6. *Failure of silicon implant in carpometacarpal arthoplasty [4].*

Silicon Swanson implant can be used mainly in wrist joints replacements [16]. Silicone biomaterial is one of the most applied materials to joint and hip replacement from 1960. The main locations of carpal joints where silicon implanted are metacarpophalangial joints (MCP), proximal interphalangeal (PIP) joint and thumb carpometacarpal joint (CMC).

The thumb carpometacarpal (CMC) joint is a common area of osteoarthritis. Researchers find out that, ligament reconstruction and tendon interposition has been more successfully than silicon implant. Silicon implant is resulted implant failure and silicone synovitis in CMC joints.For CMC joints metal, plastic, pyrocarbon and other implants were also reported [4].

Advantages of silicone arthoplasty are the ease of insertion and acceptable range of the motions. The main disadvantages of silicon are lack of stability and implant failure, which can lead to silicone synovitis. The silicone synovitis can appear in PIP joints more than MCP joints, however this failure mostly happens in carpal implants.

Titanium

Titanium has a sufficient compatibility with biological environment. This material has parallel structure. The main properties of titanium are; *high strength, low modulus, corrosion resistance and high capacity* to attach to bone and other tissues as well. Ti and Ti-6Al-4V are commonly used as implantable biomaterials [13]. These materials show the highest biocompatibility and durability in a human system.

Titanium alloys with high friction can cause wear debris results inflammations such as loosening of the implant. For solving this problem there are surface treatment techniques such as plasma spray coating and ion implantation. The most challenging factor of titanium and titanum alloys is development of an appropriate surface treatment that can increase wear resistance of the implant. Titanuim is mostly applied in metacarpophalangial implants. Metacarpophalangial joints can be observed from figure 2.7.

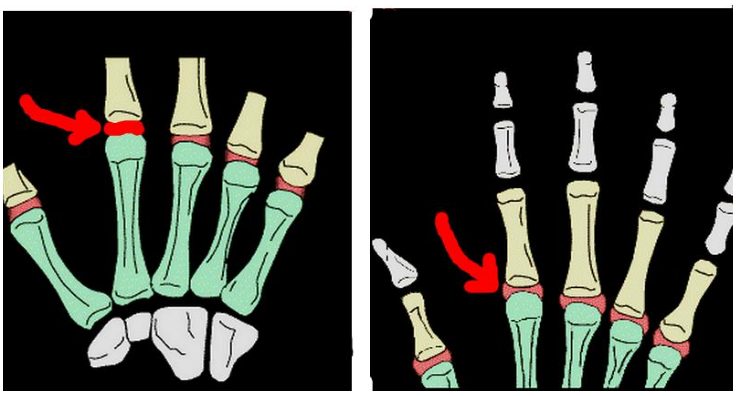


Figure2.7. *Metacarpophalangial joints [17].*

Pyrocarbon

Pyrocarbon implant is mainly used for radiocarpal, midcarpal, base of the thumb and head of capitate replacement [18; 19]. Pyrocarbon is used in patients from 1989 [18]. Researches observed that this material have higher range of motion in the wrist . The main disadvantage of pyrocarbon is implant loosening ,which was resulted in long-term follow up. Figure 2.8 shows the main locations, where Pyrocarbon implant is used.

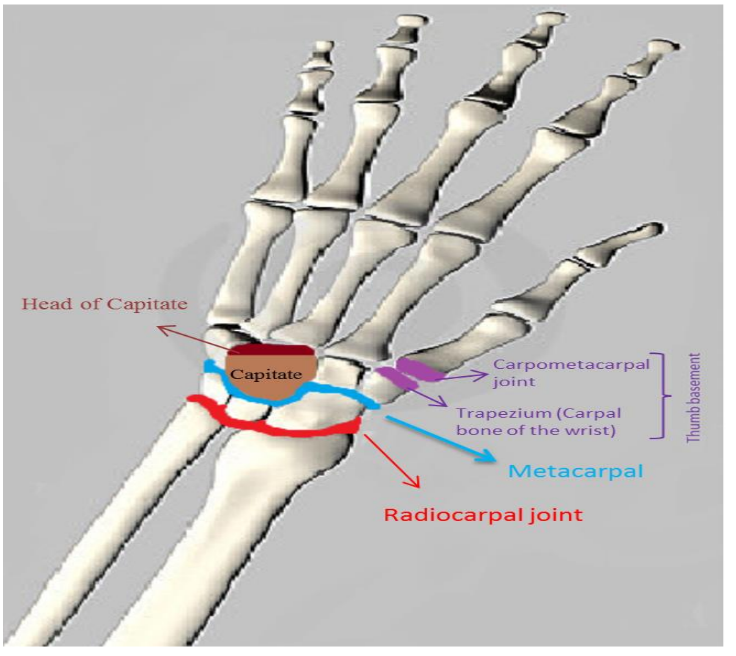


Figure 2.8. *Pyrocarbon implantation parts in a wrist anatomy.*

Poly-96L/4D-Lactide, Polyglycolide (PGA), polylactide (PLA), bioabsorble PLDLA implant

PGA is a first bio absorbable implant which has high strength rate for the fractures, but because this material is hydrophilic, it degrades faster than hydrophobic materials. So this material is not used for longer-time bone implantations [20].

Polylactide acid (PLA) is a hydrophobic polymer which has two isomeric forms, L and D isomers. The L isomer has higher mechanical strength and the degradation rate is slower than D isomer. L isomer is often found in human tissues. L-lactide is semi-crystaline and is more commonly found, while D-lactide is much less common and amorphous. Poly–L-lactide acid (PLLA) was mainly used in orthopedic fixation implants. PLLA has long degradation time compared to PGA and PLA. Poly L/D lactide acid is the combination of both L and D isomers. The degradation rate and strength of Poly L/D lactide acid is dependant on the rate of the L and D monomers.

Bioabsorbable polymers such as PLLA are required for RA patients as; these materials have long degradation time. A porous poly L/D lactide copolymer implant with the ratio of (P (L/D) LA 96/4) is totally bioabsorbable material. The bioabsorbable PLDLA implant have a porous structure, which allows tissue to grow inside. Figure 2.9 shows PLDLA implant and Swanson silicon implant.

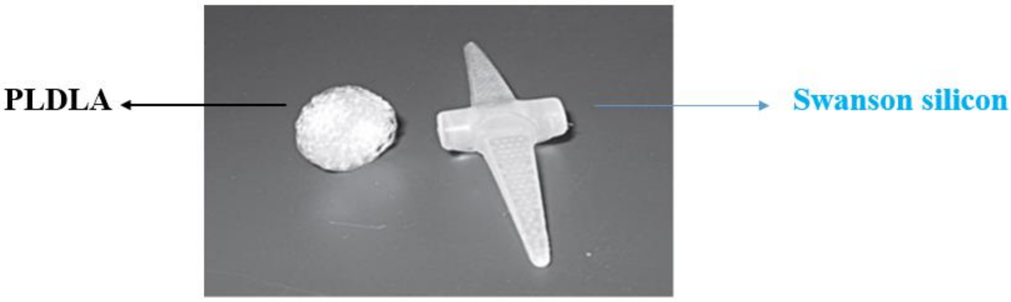


Figure 2.9.*PLDLA and Swanson silicon implant [21].*

PLDLA (POLY-96L/4D-Lactide) and Swanson silicone are used in MCP (Metacarpophalangeal) joint. In comparation of PLDLA and Swanson silicone, the reaserchers found out that dislocation of PLDLA is higher than Swanson silicone. Bioabsorbable PLDLA can also apply as a tendon interposition in the TMC (trapeziometacarpal) joint [21].

2.3.2 Design

For MCP joint replacement there were several prosthetic designs. The main basic designs can be classified in to the flexible prosthesis, the hinged prosthesis and the third generation resurfacing prosthesis [22]. Figure 2.10, is showing the designs of MCP joint.

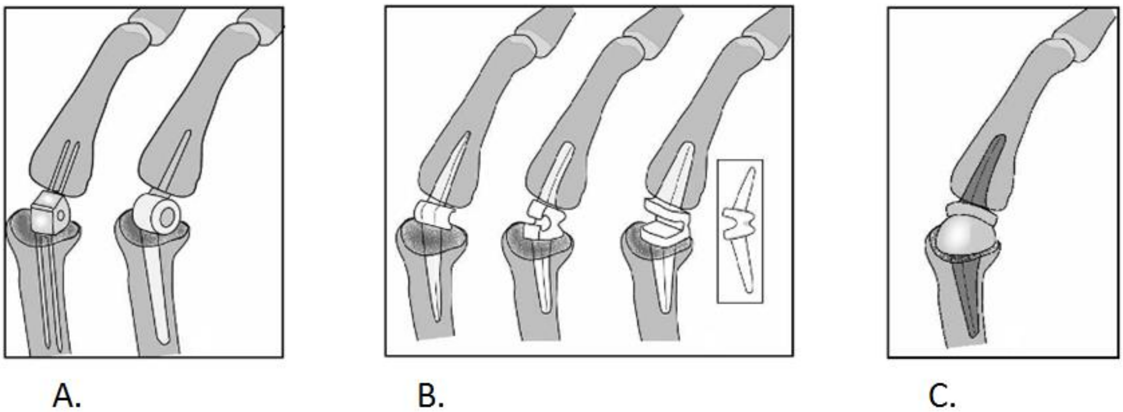


Figure 2.10. *A MCP joint prosthesis designs. A) Hinged implant, B) flexible designs and C) resurfacing prosthesis [23].*

The hinged prostheses designs are the earliest design for metallic implants. This type had high failure rate. Flexible prostheses were made of silicone rubber was developed by Swanson in 1964. Flexible prostheses designs are still the golden standard in MCP joint replacement in RA patients. Several third generation resurfacing prostheses were produced and implanted, however implant fractures, dislocations and bone loss have been reported. Reproducing the anatomical rotation and fitting better in to the phalangeal and metacarpal bone are the main targets of the prosthetic design [23].

2.4 Clinical, animal and bench test

Wrist implants were tested for observing the behaviour of the implant in different conditions. The implantation can be performed in different carpal, metacarpal and proximal interphalangeal joints. Rheumatoid arthritis is an inflammatory disorder that affects the synovial joints and causes loss of joint motion and disloctions of bones. The aim of testing the wrist implants is to improve the fixation of the implants and the joint motions.

Biocompatibility is one of the most important tests which should be evaluated before implantation of any material in the patient´s wrist. In this clinical test the duration and body reaction to the biomaterials can be determined. The clinical test of pyrocarbon material in the wrist is based on the measurements of the flexion and extension by using a goniometer. The flexion and extension movements can be seen in figure 2.11.

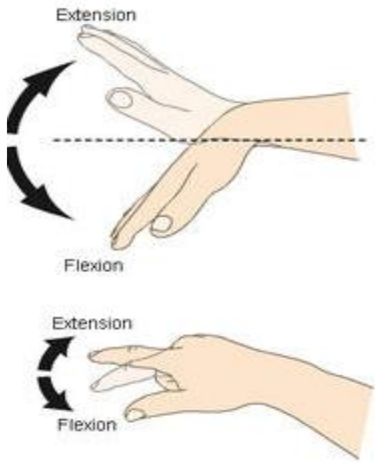


***Figure 2.11**. Flexion and extension movements of a wrist [24].*

2.4.1 Bench-Test

Bench-test can determine the biomechanical movements of the injured joint. The distal radius fraction is the most common problem of joint injuries. The bench test can estimate the flexion and extention motion of wrist joint. The agonistic and antagonitic forces are mainly activated by five pneumatic muscle motions which are extensor carpi radialis longus and brevis (ECRL and ECRB), the extensor carpi ulnaris (ECU), the flexor carpi radialis (FCR) and the flexor carpi ulnaris (FCU). From bench test the pressure can be measured.

Several bench tests were applied for determining the motion of the wrist joint by researchers. Erhart and co workers determine the pressure with a force controlled test bench and the effect of sensor insertion on the range of motion (ROM) [25]. First the sample is fixed to steel wires and connected to the pneumatic muscles. The pneumatic muscles contained 3.5 bar compressed air. A tendon force was applied to all of the samples, for recording the measurements of the motion, an ultrasound based 3-D was used.

The bench test set up can be oberved from figure 2.12.

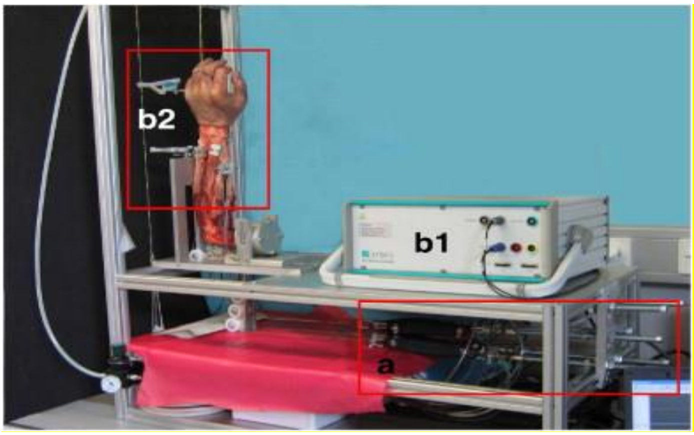


Figure 2.12. *The test set up with an artificial specimen a) pneumatic muscle b1) motion analysis system b2) tracking devices [25].*

In other study of biomechanics of wrist joints Erhart compared scaphoid and lunate pressure. These biomechanical measurements can estimate the cavity of the surface joint.
The samples were CT-scanned twice, first before biomechanical test, they were CT-scanned to observe the cavity depth of the joints, and then they CT–scanned after the biomechanical testing to measure the cavity depth changes at the radial joint surface. The results showed that the cavity of the distal radial surface was modified, which can cause changes in the wrist joint in long term. To over come this infection, the normal range of motions in distal radius should be regenerated [26].

Werner et al described the hybrid position-force algorithms which are mainly used for determining the flexor and extensor forces of a wrist. Static loading technique and dynamic testing were explained as well. In static loading techniques the loads can be applied directly by force to the metacarpals or to the wrist by weights. The forces in the radius and ulna; and the pressures on the radial-ulnar carpal joints can be measured by load cells, pressure -sensitive film and pressure-sensitive rubber. Dynamic testing of the wrist joint determines the carpal bones movements during the wrist motion. Wrist tendon forces during the forearm movement can be described from dynamic testing as well [27].

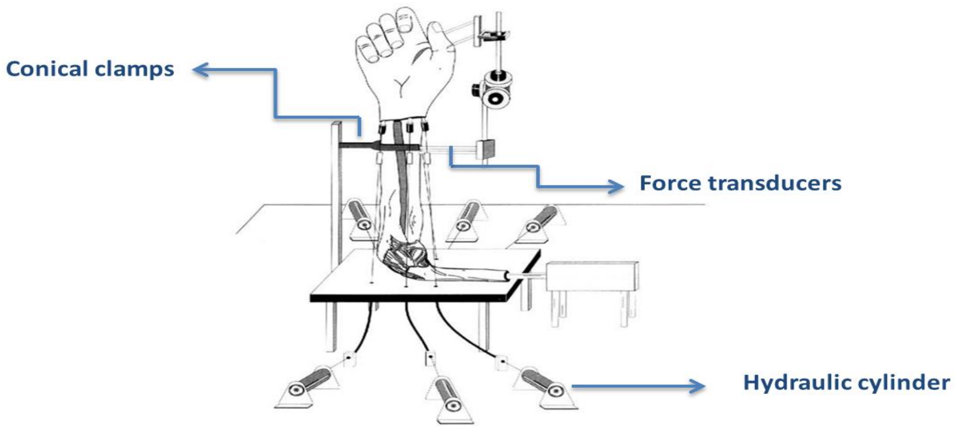


Figure 2.13. *Wrist joint motion stimulator [27].*

Figure 2.13 shows the wrist joint motion stimulator. It consists of 6 hydraulic cylinders. Hydraulic cyclinders apply force to each wrist tendons. The measurements of the forces were estaminated by force transducers which are connected in series with wrist tendon by conical clamps.

2.4.2 Clinical test

Raymond et al reported that goniometer can provide information about the range of a wrist motions (ROM) in clinical testing. The goniometer was used to determine wrist positions in flexion / extension and radial/ distal motion changes. This device can be easily applied in labrotary for measuring the wrist angular displacement of flexion/ extension and radial/distal planes.To get appropriate results, the size and physical location of the goniometer should be carefully noted [28]. The goniometer system can be seen from figure 2.14.

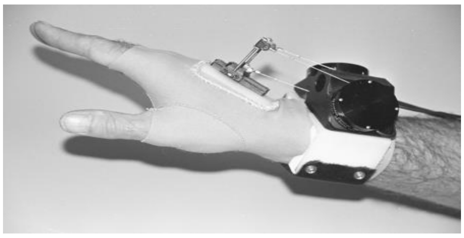


Figure 2.14. *Wrist goniometer [28].*

Other clinical tests include: scaphoid shift test (SST), the ballottement test (BALLOT) and the ulnomeniscotriquetral dorsal glide test (UMTDG). SST is used for the scaphoid bone. The examiner determines the scaphoid bone stability by his/her thumb pressing pressure. BALLOT is used to determine the fixation of lunotriquetral joint, the examiner evaluate this test by lunate bone. UMTDG is increasing the movements between the distal ulna bone, the meniscus, and the triquetrum. Lastayo et al studied the comparison between these tests. They resulted that these tests are beneficial for the patients who needed more detailed diagnostics [29].

Pieske et al compared the hydroxyapatite coated pins with stainless steel pins in another clinical study. HA and stainless steel are used for applying on unstable fractures of the distal radius. From research works, there were no significiant differences between titanium alloy and stainless steel. In orthopedics, HA was used for coating the implant surface. The main property of HA is appropriate contact between bone and pin. However HA coated pins results in infection and loosening during the six weeks. HA did not show sufficient results in clinical testing and it causes deep infection and complications in short time. By fixing this material for long term (160 days), HA-coated pins reduces the loosening rate compare to the short term used. So researchers did not recommend HA pins for general use in fixation of the wrist fractures [30].

2.4.3 Animal models of RA

Animal models of arthritis have been used to identify new targets for drug therapy and new therapeutic agents for RA. Animal amodels are also play a critical role in the development of drugs for treating RA. Mainly rodent models such as mice, rats and minipigs are used often for RA disease.

The most commonly used models in RA are streptococcal cell wall (SCW) arthritis model in rats, the collagen induced arthritis (CIA) in rats and mice and adjuvant induced arthritis (AIA) in rats [31; 32]. From the animal tests the genetic mechanisms during the early stages of RA can be studied. The collagen induced arthritis (CIA) model is the easiest and best known model for the mice because it can share the immunological and pathological features of RA. However in rat models, Hegen and co-workers claimed that in rat CIA model arthritic disease is less common and less critical than AIA model [32]. Table 2.2 is showing the different RA models in rodents [31].

Table 2.2 *Rheumatoid arthritis models in rodents*

Rat models	Mouse models
Streptococcal cell wall (SCW)	collagen induced arthritis (CIA)
Adjuvant induced arthritis (AIA)	Pristane-induced Arthritis
Adjuvant arthritis (AA)	Proteoglycan-induced arthritis
Pristane-induced arthritis (PIA)	Zymosan-induced arthritis
	Immune complex arthritis
	Serum transfer models

Conclusively, the animal tests can be applied to humans for overcoming the RA in the early stages. The important facts in selection of a model include similar pathology to human disease, ease of performing the model and also ability to predict efficacy of the agents in humans [33].

2.5 Comparison of reported benefits

2.5.1 Applied materials

In hand surgery, pathology of the proximal carpal row is one of the main challenges. The main fractures in proximal carpal row can be observed in scaphoid and lunate bones. These failures mainly happen in young people. The main material which was used successfully for replacement of lunate and scaphoid is silicon. The surface property in implants are categorized to *Texture* and *Net charge* surfaces. The *texture* surface can be smooth or microtextured and *net charge* surface is devided to charged and uncharged surfaces.

The surface of silicone is smooth and uncharged, where as the most of the implanted materials have microtextured structure. The smooth surface of silicone affects the formation of fibroblast cells. Microtextured implant surfaces increase macrophage and giant cell proliferation. More over, uncharged surface of the silicon elastomer implant increase the formation of a capsule with fewer inflammatory cells compare to other implatable materials with charged surface. So silicone elastomeric is relatively good implant in terms of its ability to control the inflammatory cell propagation [14].

The clinical success of joint replacement implants mainly depends on two main factors, which are; 1. Osseointegration and primary fixation of the implant in few months and 2.Fixation of the implant for long term. By comparing several biomaterials, PLDLA do not have any harmfull effects on the human system and also do not cause swelling and inflammations in a body. Figure 2.15 shows the PLDLA RegJoint implant [34].

Figure 2.15*.PLDLA implant [34].*

2.5.2 Bench test

Erhart et al., measures the pressure and the influence of sensor insertion on the ROM (range of motion), they conclude that sensor insertion decreases the range of the motion. The motion reduction can be related to not compeletly adaptation of the sensor to the joint surface [26]. The applied forces of different resarchers were compared in table 2.3.

Table 2.3. *Comparison of applied forces by different researchers [26]*

Hogan Lunate fossa pressure	0.4 MPa
Erhart Lunate fossa pressure	0.4 MPa
Short Peak pressures of flexion and extension	1.3 and 1.7 MPa at 24 º
Erhart Peak pressures of flexion and extension	1.6 and 2.7 MPa
Short applied tendon forces	255N
Erhart applied tendon forces	275 N

Erhart et al found that the cavity of the distal radial surface was modified when the biomechanics of wrist joints and cavity of the distal radial surface was observed, and this can cause changes of wrist joint in long term. For improving this infection the distal radius normal shape and motions should be regenerated in future to overcome arthritis.

2.6 Drawbacks of the predictable and reported techniques

Drawing from several research work already done on wrist implant. The main requirements for future wrist implant include stable materials and improvement the main functional motion of the wrist. None of the several implant options is biologically inert [14].
A normal wrist rotation has flexion-extension and radial-ulnar movement. Researchers suggested designing a wrist implant with limited but essential range of wrist movements. The main problem that was considered in the existing designs of wrist implant was loosening and swelling of the metacarpals. Future implants can also achieve interference fit. It is the most appropriate method for fixation of the implant. Titanium screws by implanting in to the radius and second and third metacarpals can be used for fitting and fixation as well. Most of the materials which are used for wrist implant are metal-on polymer joints. The materials which are used for implantation should have approximately similar modulus of the bone. Polymers are good samples of materials to achieve this target.
There are several failures in joint implants.The most common reasons for removing the implants are; implant fracture, implant loosening and infection. These failures were determined by x-ray imaging [16].

From several biomaterials, bioabsorbable 96L/4D poly L/D lactide copolymer fiber (PLDLA) can be sufficient for applying in RA diseases. The main reasons such as bioabsorbable, porous structure and high mechanical properties make this material suitable for joint replacements in MCP and TMC. In the following study, the implantable biomaterials will be discussed more in details.

3. MATERIAL AND METHODS

3.1 Wrist Bones

The wrist consists of 8 carpal bones which are categorized in two rows, proximal row and a distal row. The proximal carpal row consists of four bones; scaphoid, lunate, triquetrum and pisiform. These bones are attached to each other by intercarpal ligaments; the scapho-lunate and lunotriquetral. The distal row consists of; trapezium, trapezoid, capitate and hamate, which are attached to each other by strong intercarpal ligaments [35]. Figure 3.1 shows the locations of the carpal bones in a wrist anatomy.

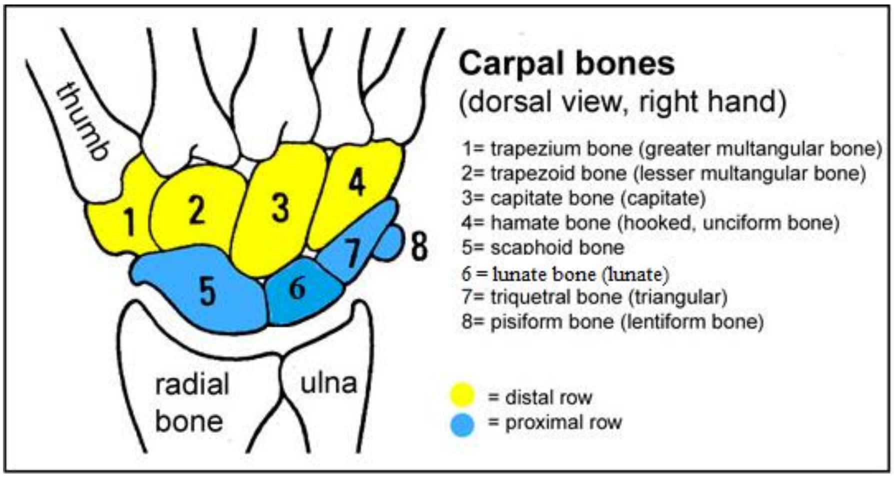


Figure 3.1 *.Carpal bones [35].*

3.1.1 Trapezium bone

The trapezium bone is one of the eight carpal bones, which is situated at the radial side of the carpus between the scaphoid and the first metacarpal bone (the metacarpal bone of the thumb). Arthritis in this joint is very common which leads to increasing stiffness and deformity in the thumb. In this condition trapezium joint does not protect the joint tends to stiffen. This study is more concentrate in trapezium bone, trapezium failures and the possible treatments for trapezium bone. Figure 3.2 is the schematic of trapezium bone.

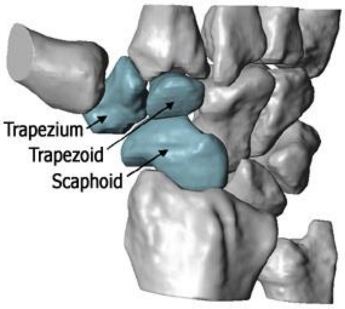


Figure3.2. *Trapezium bone [36]*.

There are mainly four trapezium articulations which are; trapeziometacarpal (TMC), scaphotrapezial (ST), trapeziotrapezoid and trapezium –index metacarpal. Most forces of the thumb are loaded on TMC and ST joints, for this reason bone arthritis were mainly affected on these joints.

3.2 Basal joint arthritis

Basal joint is a joint at the base of the thumb which, the main movements of the thumb are reffered to the basal joint or carpometacarpal joint (CMC). Basal joint is formed by small bone of the wrist (trapezium) and first bone of the thumb. Schematic of basal joint can be seen in figure 3.3.

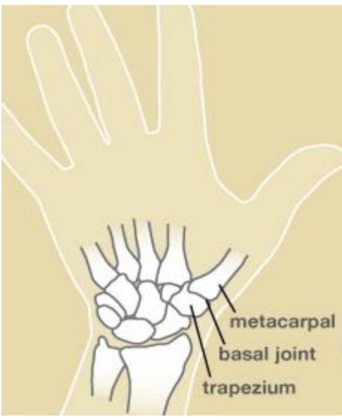


Figure 3.3. *Basal joint [37]***.**

Basal joint arthritis mainly can be seen in postmenopausal age group of women. There are several types to treatment the basal joint arthritis. The common treatment is perform a total joint reconstruction; which the trapezium bone at the base of thumb is removed. The main reason for removing trapezium is connection of this bone to three other bones that can improve the arthritis. Then for providing and supporting the thumb position, the connection between the near sides of the thumb and index finger by tendon graft can be done. Finally a cushion which is usually made from a tendon graft can be used for protecting the space between the bones where the trapezium bone used to be.

3.2.1 Fractures of the trapezium bone

Trapezium fractures are rare but can be occur by osteoarthritis in body of the bone and trapezoid ridge. If the fracture occurred on the surface level, casting could be applied on the bone. The intra-articulare fractures can be fixed by using k-wires or screws. The excision of the fracture fragments of trapezial ridge should be treated by surgery. Figure 3.4 shows the trapezium fracture site.

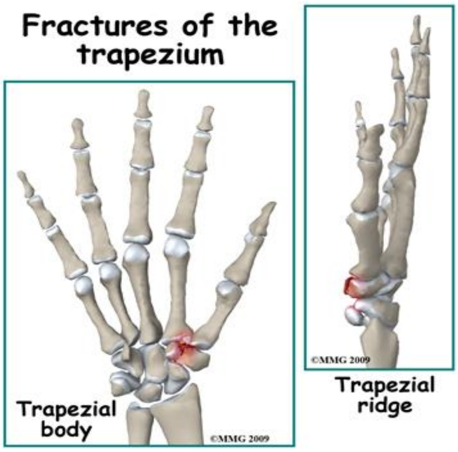


Figure 3.4 *Fractures of trapezium bone [38].*

3.2.2 Trapezium bone arthritis

Arthritis at the base of the thumb is the most common site of osteoarthritis in the hand. Osteaoarthritis of the trapeziometacarpal joint (TMC) is a common problem in postmenopausal women. Typically it starts from inside of the trapezium, figure 20. Then it will improve and include the other sites of metacarpal joints.

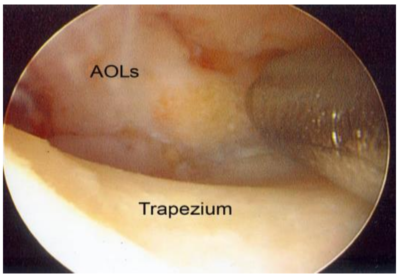


Figure 3.5 *Arthroscopic image of Trapezium bone and AOL (anterior oblique ligament) [39].*

Table 3.1. *Main Stages of trapeziometacarpal joint arthritis*

Stages of trapeziometacarpal joint arthritis	
Stage 1.	• Pain at the basement of the thumb with no deformity • Crepitus refers to the abrasion of fractured bone surfaces which resulted painful feeling with crunching sounds • Osteophyte
Stage 2.	• Pain • Crepitus • Minimal subluxation (dislocation of joint) of the metacarpal and metacarpophalngeal joint
Stage 3.	• Increasing the subluxation of the metacarpal base • Hyperextion of the metacarpal joint <10 º
Stage 4.	• Enhancement of subluxation of the metacarpal greater than stage 3 • Hyperexion of the metacarpal joint > 10º
Stage 5.	• Trapeziometacarpal joint arthritis along with scaphotrapezial arthritis

Eaton and Litter radiographic classification of Trapeziometacarpal(TM) Osteoarthritis (OA)

Litter and Eaton described a radiographic classification for treatmenting in trapeziometacarpal osteoarthritis. Recent studies are also applying this classification for trapezium treatment as well.

Stage I.	Comprises normal articular surfaces with out joint space narrowing. Subluxation < 1/3.
Stage II.	Joint space narrowing. Osteophytes <2mm in diameter. Subluxation > 1/3. STT joint (scaphoid-trapezium-trapezoid) is normal.
Stage III.	Significant joint space narrowing. Osteophytes > 2mm in diameter. Normal STT joint.
Stage IV.	Pantrapezial OA which is termed to Osteoarthtitis of carpometacarpal (CMC) and scaphotrapeziotrapeziod (STT) joint with narrowing. Osteophytes involving both in TMC and STT joints.

Patients involved in stage II and early stage III can be treated with hemiresection arthroplasty, which means the approximately removing of trapezium bone filling by tendon. In stage IV the partial and total resection of TM and STT due to the osteoarthritis situation should be applied. The main disadvantage of any resection treatment is weakness of thumb pinch strength. In following section the main tendons which are used for trapeziectomy treatment will be discussed.

Thumb basement tendons

Several surgical techniques have been applied for TMC osteoarthritis, the main tendons which were used for applying on thumb basement can be seen in figure 3.6.

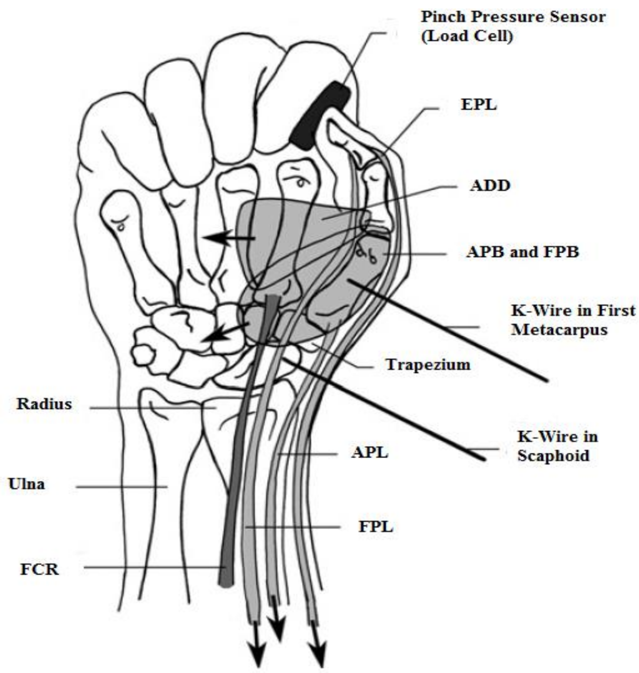


Figure 3.6. *Thumb tendons: extensor pollicis longus (EPL), adductor pollicis (ADD), abductor pollicis brevis (APB) and flexor pollicis brevis (FPB), flexor pollicis longus (FPL) and abductor pollicis longus (APL), flexior carpi radialis (FCR). K-wires are used for measuring the changes of thumb metacarpal and scaphoid [40].*

3.3 Treatments of Trapeziometacarpal joint arthritis

Fractures of trapezium bone are rare. The main defect of trapezium arthritis is osteophyte which can result a painful force between the metacarpal base and trapezium bone. Osteophyte refers to small abnormal out growth of the bone which can be seen in figure 3.7. In addition arthritis can also involve lower surface of the trapezium, where it joints the scaphoid bone. This is termed to the scaphotrapezial trapezoidal (STT) joint.

Figure 3.7. *Osteophyte or bony growth in trapezium bone [41].*

One of the most common causes of removing trapezium bone is thumb arthritis. Recently researchers are resulted that, forces at the basement of the thumb are 12 times greater than the tip of the thumb. Trapeziometacarpal joint is located between the trapezium and first metacarpal. For diagnosis of the osteoarthritis in the basement of the thumb commonly x-ray imagings can be applied in clinical examinations. The first treatments of trapezium bone for relieving discomfort include activity modification, pain killers, splints, steroid injection and surgery. These treatments will be discussed more in the following study.

First step: the primary treatment is rest and prescribtion of non-steroidal anti- inflammatory medications.
Second step: If the first step was failed, splint for the hand and thumb can be the second treatment. However; most patients do not accept the splint since it reduces thumb functions.
Third step: Another treatment is an injection of corticosteroid in to the trapeziometacar pal joint. This option can be reducing the pain of early stages arthritis if advanced stages could not be succeeded.
Forth step: The final and fourth step for treating the osteoarthritis in trapeziometacarpal joint is surgical treatment.

3.3.1 Trapeziectomy (Excision of the trapezium)

Trapeziectomy treatment is the complete removal of the trapezium bone. It has been required when the above and below joints of trapezium are arthritic. Simple trapezial excision with out soft tissue interposition first was described by Grevis in 1949 [42]. This treatment resulted the shortening of the thumb and migration of the proximal metacarpal joints. However after the operation the movement and adjacent of the thumb to the scaphoid and trapezoid bones can be occurred. This movement may cause instability and weakness of the thumb that may require reoperation. Therefore a number of treatments were reported for solving the trapeziectomy problem.

A number of tendons such as flexor carpi radialis (FCR), extensor carpi radialis longus (ECRL) and abductor pollicis longus (APL) were applied with trapeziectomy operation. In this surgery, the trapezium bone at the base of the thumb is removed and an extra wrist tendon (mainly flexor carpi radialis tendinitis tendon) is released in the mid – forearm and placed at the base of the thumb. The Excision surgery steps can be seen in figure 3.8.

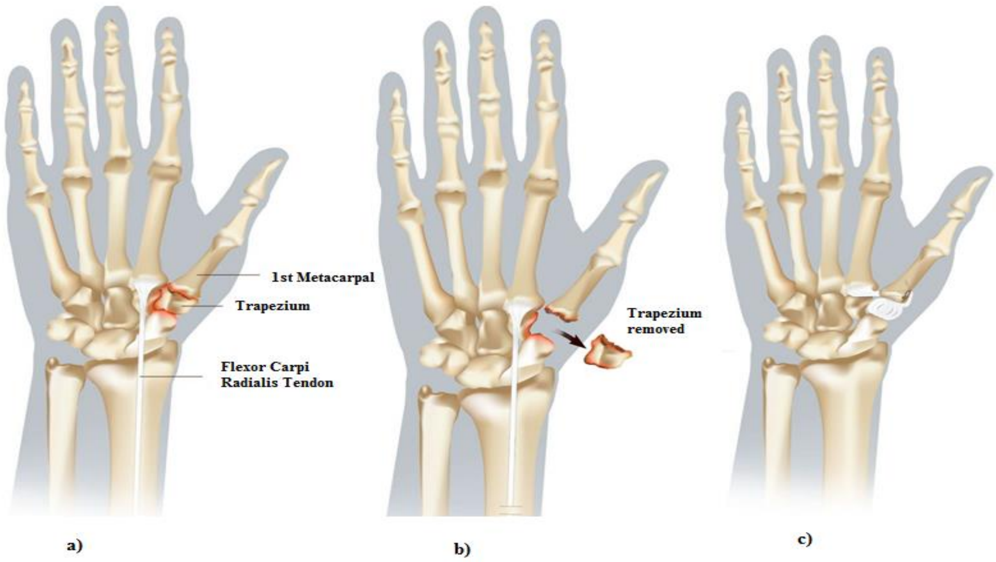


Figure 3.8. *Excision of trapezium bone, a) Osteoarthritis in trapeziometacarpal joint,b) Extract of trapezium bone c) flexor carpi radialis tendon replaced at trapezium bone [43].*

3.3.2 Trapeziectomy with ligament reconstruction and tendon interposition (LRTI)

The most popular technique for operative treatment of trapeziometacarpal osteoarthritis is trapeziectomy with ligaments reconstruction and tendon interposition (LRTI). LRTI indicated for the patients with basal joint arthritis or CMC instability. LRTI involves partial or complete resection of the trapezium bone. Following these process patients can expect significant long term increase in grip and pinch strength. Trapeziectomy with ligament reconstruction can be divided in two main groups, which are partial and total trapeziectomy; *LRTI-PT*: Trapezium metacarpal affected hands, treated by ligamentoplasty with partial trapeziectomy and *LRTI-TT*: Hands with proximal and distal trapezium affected surfaces, treated by ligamentoplasty with total trapeziectomy [44].

García claimed that the partial trapeziectomy could be better treatment than total trapeziectomy. He was resulted better pinch strength and sufficient hand movements by partial trapeziectomy with ligament reconstruction method. Ligament reconstruction with tendon interposition (LRTI) arthroplasty was described by Burton and Pellegrini in 1986 [45]. Several tendons have been used for ligament reconstruction, including flexor carpi radialis (FCR) and palmaris longus tendon of the hand which are shown in figure 3.9.

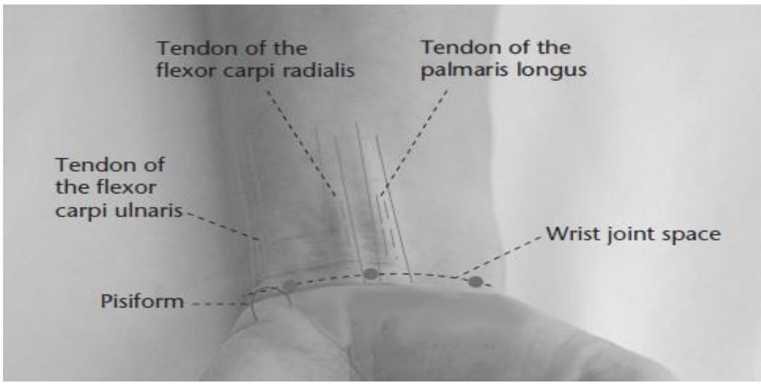


***Figure 3.9**. Tendons (flexor carpi ulnaris and tendon of the flexor carpi radialis) used for Ligament reconstruction [46].*

Trapeziectomy with ligament reconstruction and tendon interposition (LRTI) using half of flexor carpi radialis (FCR) (T+LRTI)

After trapeziectomy, the FCR tendon was harvested from radial forearm incision for reducing thumb shortening and improving pinch strength. A hole was drilled in thumb metacarpal and the FCR tendon is passed through a drilled hole for reconstruction the ligament and the remaining FCR tendon is placed in to the space which was left by the trapeziectomy.

From several studies, T+ LRTI used a K-wire and a thumb spica cast .The stability between scaphoid and the thumb by K-wires was improved [47].

Figure 3.10 shows the main steps of trapeziectomy with ligament reconstruction by flexor carpi radialis tendon.

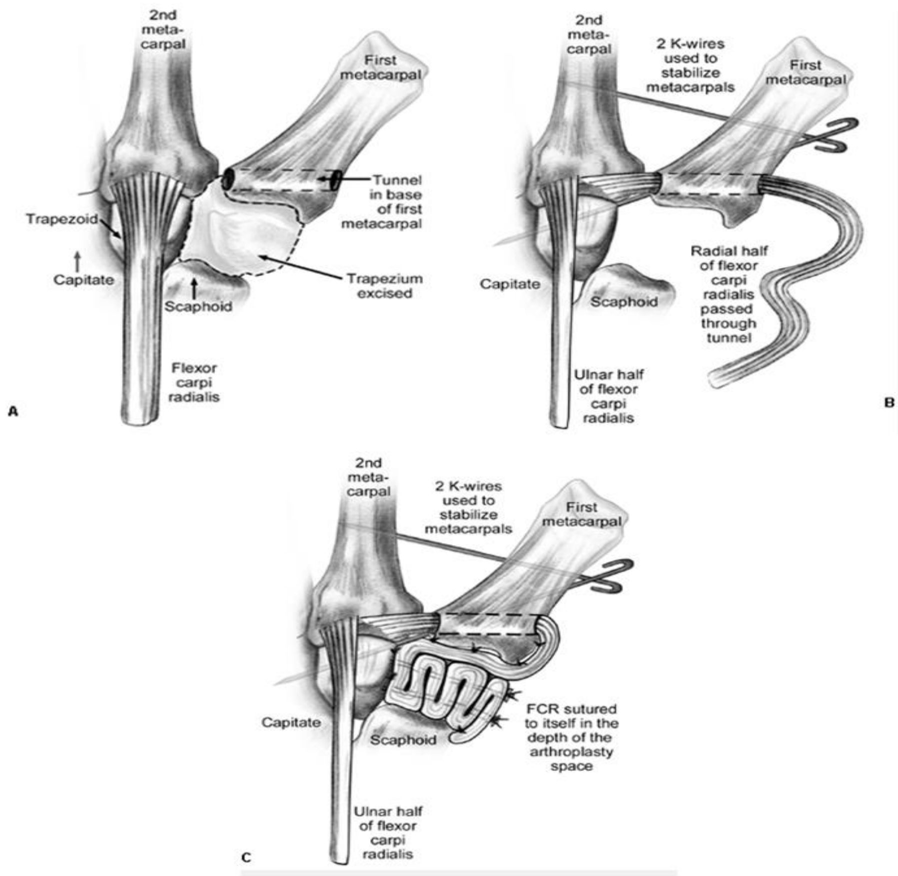


Figure 3.10. *Trapeziectomy with ligament reconstruction with tendon interposition (FCR), A. after excision of trapezium bone (Trapeziectomy), a tunnel is drilled from proximal palmar to distal dorsal through the thumb metacarpal. B: The flexor carpi radialis (FCR) tendon is harvested proximally and passed through the drill hole and two K-wires are used for stabilizing the metacarpals. C: The remaining FCR looped and sutured to it self in the thumb basement [45; 48].*

Trapeziectomy with palmaris longus tendon interposition (T+PL)

Palmaris longus tendon also can be applied in TM joint arthritis with trapeziectomy treatment. This procedure is the same as FCR tendon interposition after trapeziectomy but palmaris longus tendon is harvested instead of flexor carpi radialis tendon.

Trapeziectomy with ligament reconstruction and the extensor carpi radialis longus (ECRL)

Illaramendi and co workers studied the ligament reconstruction with the extensor carpi radialis longus tendon (ECRL) for osteoarthritis of the trapeziometacarpal joint. The surgical method was the same as ligament reconstruction with flexor carpi radialis tendon (FCR) method but the harvested tendon was ECRL and dorsal incision is made to expose the ECRL tendon. They concluded that, in this method harvesting of ECRL is more difficult than FCR tendon and also they have found out the tendon interposition is unnecessary for reinforcing the ligament reconstruction [49].

3.3.3 Arthroscopy in the treatment of fracture of trapezium bone

Arthroscopy is a minimally invasive surgical procedure. It is mainly used for treatment of bone fractures by inserting an arthroscope to the joint through a small incision.
The imaging anatomy of trapezium surface is challenging and complex by simple radiographs. For this reason the minimal invasive method of small joint arthroscopy can be applied [50].

Clinical treatment of shear fracture in trapezium bone can be done by arthroscopic instrumentation including use of 1.9 mm small joint arthroscopic. It was inserted from the radial carpometacarpal (CMC) part in to the CMC joint for visualization of the joint surface of trapezium bone. Kirschner wire (K-wire) with 0.035 inch is used for fixation of the fractures and fixing the fragments. Then the definitive fixation is performing by an Acutrak headless screw, which is acrossed the fracture to compress the fragments.
After surgical treatment the patient should be protecting his/ her hand by placing in a thumb spica splint for about 3 weeks. Then the patient can participate to physiotherapy for improving the movements of the wrist joints approximately in 6 weeks [50].
Desmoineaux and co-workers estimated the arthroscopic trapezioctomy with ligament reconstruction for treatmenting thumb basal joint osteoarthritis. This treatment is mainly applied on thumb carpometacarpal (joint) arthritis. By this treatment a metal finger trap was placed on the thumb phalangeal, then two vertical lines were drawn parallel. For surgery the thumb should be placed on the dorsoradial side, then the reamers were applied on the basement of the thumb for removing the osteophytes and foreign bodies. The trapeziectomy is also done for trapezium bone resection. Then by drilling the dorsoradial portal, a tunnel was made at the base of the thumb at the second metacarpal.

The required transplant length was determined by measuring the distance between the lateral edge of the trapezium and the base of second metacarpal. The approximate range by Desmoineaux and co-workers was determined about 36mm. The required abductor pollicis tendon was cut and by k-wire placed in the tunnel and fixed by bioabsorbable screw. Then the incisions were closed by sutures [51]. The main advantage of this treatment is, it can be included for young patients who are 40-60 years old. From Figure 3.11, the main steps of arthroscopic trapeziectomy with ligament reconstruction can be observed.

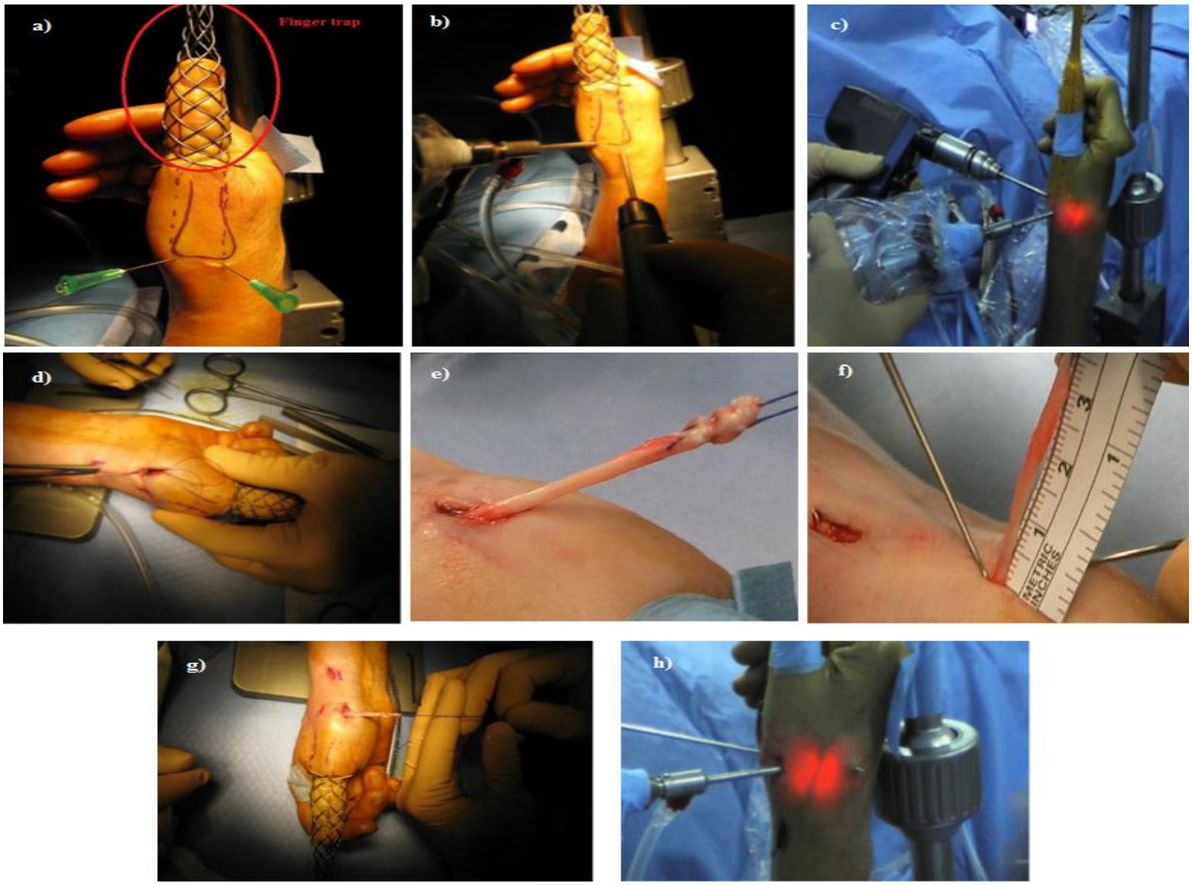


Figure 3.11. *Arthroscopic trapeziectomy with ligament reconstruction. a) Finger trap placed on the thumb, b) trapezium reaming by arthroscope, c) drilling the base of the second metacarpal in dorsal direction, d-e) harvesting the abductor pollicis longus tendon , f-g) measuring the length of the tendon , h) applying the k-wire for placing the transplant [51;52].*

3.3.4 Osteotomy

Osteotomy is a surgical operation, where bone in the base of the thumb metacarpal will be shortened. This treatment should be done to CMC arthritis that has no scaphotrapezial changes. There is no needed for K-wires in the surgery, if the procedure is done carefully enough. Osteotomy procedure is done for correction of the bone length. This treatment for trapezimetacarpal arthritis resulted in good mechanical and strength properties [53]. Figure 3.12 is showing the osteotomy procedure.

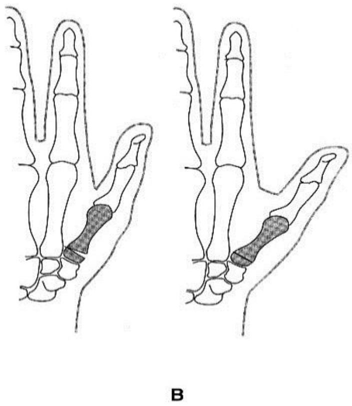


Figure 3.12*.Osteomy treatment of the thumb metacarpal arthritis; A.The proximal cut is made parallel to the metacarpal joint surface. The distal cut is made at a 30ºC angledor resection of a dorsal wedge of bone; B. The bone gap is closed and fixed [54].*

3.3.5 Arthrodesis (Trapeziometacarpal joint fusion)

Arhrodesis is the surgical fusion of two bones to provide additional stability to the joint. The operation should be performed in dorsal approach in hand. However there is no longer movement in the joint after procedure. The main goal of this procedure is to remove the pain from the joints. Nowadays arthrodesis method is not commonly applied on the patients and it is replaced with arthroplasty method [3; 55]. Figure 3.13 is showing the arthrodesis treatment in hand.

Figure 3.13*. Radiograph of Scaphoid-trapezium –trapezoid fusion (STT) [56].*

3.3.6 Silastic replacement of the trapezium

Biocompatible materials which have high tissue tolerance become more essential materials for bone and joint implantation. Designing of the implant for best fitting, stability and balance is important. Three dimentional kinematics of the wrist for best fitting the implant was evaluated by computer designing programs [7].

Silicon material can be applied on trapezium bone for treatmenting of osteoarthritis after excision of trapezium bone. The stability of silicon can be increased by flexor carpi radialis (FCR) tendon wrapped around the impland. The use of silicone implant after trapeziectomy in osteoarthritis is ignored due to the silicone synovitis, implant loosening and bone erosion. Other implants such as metallic and polyethylene have been reported but they did not improve the hand arthritis [40]. Silastic replacement of the trapezium bone will be discussed more in "Implants for trapezium bone failure" section.

3.4 Implants for Trapezium bone failure

Different kinds of biomaterials in trapezium bone have been evolved over the years. These materials are mainly used as interpositional materials for treatment of trapezium bone failures. Researchers found out the implant arthroplasty preserves joint biomechanics and provides stability. There were several developments of trapezial prosthesis implants including synthetic interposition materials, metal joint arthroplasties and pyrocarbon trapezial arthroplasties. There are various interposition materials where implanted in trapezium bone. Table 3.2 shows the interpositional materials of trapezium bone in partial and total trapezial resection

.

***Table 3.2**. Biomaterials of Trapezium bone.*

Interpositional Material of trapezium bone	
Partial trapezial resection	Permanent
	Pyrocarbon
	Temporary
	Artelon
Total trapezial replacement	Silicone Metallic Pyrocarbon

3.4.1 Silicon

Trapeziectomy with silicone arthroplasty for replacing TMC joint first was described by Swanson and co-workers in 1960 [57]. The main target of silicone rubber trapezium implant arthroplasty was to provide mobility and stability. The shape of implant was modified from a convex to a convey surface which provided more stability in the rounded distal pole of the scaphoid. In silicon replacement surgery, the best fitting implant should be selected [58].

Silicone elastomer implant was mentioned by Shai Luri and co-workers on 2007. The implant stem is inserted in to the metacarpal and the base is seated on the scaphoid. In some cases when quality of the tissue is poor, then the stability of silicone can be increased by flexor carpi radialis (FCR) tendon. This tendon wrapped around the impland. They also concluded that the biomechanic treatments of synthetic implants are greater than trapeziectomy treatments [40; 57; 58; 59]. The silicone arthroplasty of TMC joint can be seen in figure 3.14.

Figure 3.14. *Silicone arthroplasty 5 years after operation [7].*

The investigators concluded that silicone hemiarthroplasty of trapezium could be satisfactory for low demand of osteoarthritis. Hemiarthoplasty is termed to surgical technique, which is used to replace a part of a joint with an artificial implant. Pellegrini and Burton defined four different kinds of silicone implants; Swanson trapezium, Swanson convex condylar hemitrapezium, Swanson unipolar metatarsophalangeal implant and cannulated Eaton trapezium [59]. The investigators recommended the silicone hemitrapezium and cannulated trapezium for low demand osteoarthritis [57].
By silicone implantation billions of silicone particles smaller than 15 μm were found surrounding this implant. In-vivo animal tests shows that the oxidation of silicone elastomer implant caused implant fracture [60]. Clinical studies shows there are no silicone synovitis but bone cysts in metacarpal region developed which caused dislocation of silicone prostheses [7; 59].

The main disadvanges of silicone implant are;

- Silicone synovitis which can cause radiographic translucent
- Long term implant failure
- Deformation and decreased the thumb rotations
- Radiographic subluxation
- Implant fracture
- Unsuitable for young patients who apply greater forces and activities

Figure 3.15 shows the silicone arthroplasty in TM joint differences after time.

Figure 3.15. *Silicone implant in TM joint; A. Radiograph of silicone arthroplasty after 4 years in basal joint with radiolucency aroud the implant in the thumb metacarpal, B. Radiograph of silicone arthroplasty after 7 years with also radiolucency aroud the implant in the thump metacarpal, C. Radiograph of silicone arthroplasty after 10 years showing non radiolucency surrounding the implant [59].*

3.4.2 Metallic

Metallic implants were also reported by different researchers for replacement of silicon in TM joint arthritis. These metallic implants include various combinations of metal and polyethylene components. The first metallic implanted material was made from polyethylene ball and cobalt chromium socket implant [57]. The polyethylene cup placed in trapezium and cobalt chromium stem was located in the metacarpal, figure 3.16. The results of this implant were not satisfactory enough by patients [7].

Figure 3.16.*Ball and socket metallic implant [7].*

The implant loosening especially in young men who may put more stress on the prosthesis was mentioned. The investigations found out there is a relationship between loosening of the implant and younger age. When the younger patient applies more forces to the thumb, loosening of the implant can occur. For this reason some changes were done by researchers. A cobalt chromium molybdenum alloy stem and ultra high molecular weight polyethylene cup was reported. This metallic implant resulted increasing range of motion and strength but there was also reported implant loosening in some patients. There were various studies about ball and socket metallic implant by researchers. Elektra and co-workers reported unconstrained cementless hydroxylapatite coated prosthesis. This implant resulted good range motion but also loosening of the implant is observed. The GUEPAR prosthesis was cemented cobalt chrome on polyethylene total joint implant. The Braun –Cutter prosthesis was a cemented prosthesis with a titanium stem and a polyethylene cup, the investigators suggested to use Braun implant for low activity patients with TMC arthrodesis. The Ledoux prosthesis was consisting of an uncemented ball and socket with cylindrical shape. For increasing the range of motion in this implant ionic nitrogen was applied on prosthesis head. Cooney and collegous reported another TMC total joint prosthesis, the trapezial component is made from Co-Cr alloy and the metacarpal stem is made of high density polyethylene. This implant was developed based on biomechanical studies with 3-D motion. The result from this implant was not satisfactory, it caused heterotopic bone or formation of bone in abnormal location.

Avanta SR TM was another prosthesis which is made of cobalt chrome alloy, which is located instead of trapezium bone and the metacarpal component is made of ultra high molecular weight polyethylene. In contrast to the ball and socket designs, this implant showed significant decreased pain during the activity and significant improved hand function after surgery. There was not reported any implant loosening [7]. Due to the high loosening rate of cemented ball and socket metallic implants, these implants have been reduced. Investigators recommended these implants for advanced stage of thumb CMC osteoarthritis [57]. Titanium arthroplasty is also reported for TMC joint arthritis, this implant was improved the motion and it is 1000 time stiffer than the host bone which may increases the stress at the thumb basement [7; 57].

Figure 3.17. *Radiographs of metallic implants for treatmen of TMC arthrodesis joint; a) GUEPAR prosthesis implant , b) Elekta total joint prosthesis implant , c) Braun-Cutter total joint prosthesis implant , d) Ledoux cementless prosthesis implant , e) Coonery TM joint prosthesis implant, f) Avanta SR TM prosthesis implant, g) Titanium TM prosthesis implant [7].*

The latest metal implant was developed in 2009, which was called TrapEZX, figure 3.18. There is no published data from this implant yet.

Figure 3.18. *TrapEZX metallic implant [7].*

3.4.3 Pyrolytic Carbon

Pyrolytic carbon is another material that can be applied for TMC arthroplasty. This material is produced by pyrolysis of a hydrocarbon gas. The main difference of this material with silicone, Artelon and titanium is the same elasticity modulus of pyrolytic carbon with cortical bone, which leads to better biomechanical properties same with TMC joint. Pyrolytic carbon can be implanted in total trapeziectomy combined with ligament reconstruction using the flexi carpi radialis tendon (FCR). Pyrolytic carbon implant can be observed from figure 3.19.

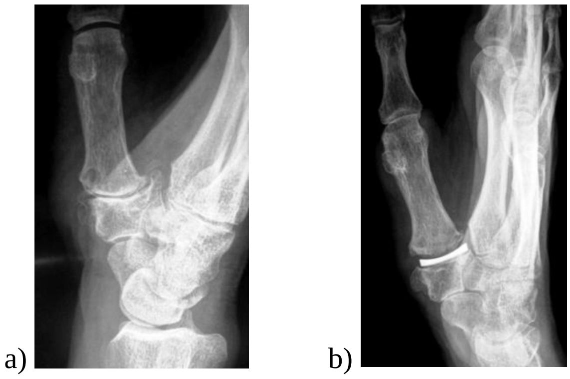


Figure 3.19. *a) Preoperative TMC joint, b) Pyrolytic carbon treatment in TMC joint arthritis [7].*

NuGrip is the currently available pyrolytic carbon prosthesis which is seated in trapezium and metacarpal bone, figure 3.20. This implant was compared to metallic total joint implants and trapeziectomy alone. It has higher loosening rate, dislocation and subluxation than reference methods [61].

Figure 3.20. *NuGrip pyrolytic carbon [42]*

3.4.4 Ceramic

Ceramic implants were also reported for treatment in osteoarthritis of trapeziometacarpal joint by Athwal and co-workers [62]. Zirconia ceramic implant was applied between the thumb metacarpal and trapezium. The results from this material were unsatisfactory for long time.

3.4.5 Goretex

Goretex material (polytetrafluoroethylene interposition) as an interpositional material resulted very good clinical experiments and pain relief. However this material caused particulate disease and high range of osteolysis in the surrounding bones. For this reason Gortex was not recommended as interpositional material [7; 57].

3.4.6 Poly-L/D-lactide Copolymer

A porous poly L/D lactide copolymer implant with the ratio of (P (L/D) LA 96/4) by thickness of 4mm and diameter 12 or 14 mm was provided by Tampere University of Technology; Finland and also was tested to observe the resorption property [21;60;63; 64,86]. PLDLA interposition implant designed to preserve its shape for long enough and allow growthof the host tissue and be replaced with fibrous tissue in 2-3 years [64].This implant was inserted in the joint space and fixed with a Kirschner wire (K-wire) [60; 64]. In the tendon interposition group flexor carpi radialis tendon was chosen because of the size and strength of the tendon. The extensor carpi radialis tendon can be also used, if FCR was not available [65].

The hand extension and flexion range of motion was determined by goniometer, and grip strength was measured by Jamar dynamometer same as measuring silicon Swanson implant. The "Box and Block"test which is picking up and leaving the boxes in 60 seconds was done for this implant. "Box and Block" test can determine the ability of hand motion. ADL test was also improved in this implant. ADL test (activities of daily living) including writing, light house work, turning a key, etc is evaluated the hand function after surgery [60]. In clinical studies PLDLA implant was reported no implant fracture, no foreign body reactions, good pain relief and non toxicity.The implant was reported to own good biocompatibility and biodegradation behavior with bone tissue. However similar to other implants, researchers were not satisfied in enough stabilization of the MCP joint by PLDLA arthroplasty [65; 66].PLDLA implant can be seen from figure 3.21.

Figure 3.21. *PLDLA implant [60].*

3.4.7 Synthetic allograft

Artelon and Graft jacket are the main two types of synthetic allograft which are used for implantation of basal joints in hand arthritis.

Artelon

Artelon is a synthetic allograft interposition [57]. Artelon is a T-shaped biodegradable polycaprolactone based polyurethane material is used for thumb TMC arthritis [7; 67]. The shape of Artelon allowed this material to implant in two regions. The vertical portion of Artelon interpositioned between the thumb metacarpal base and distal trapezium and functioned as a joint interposition, and as a ligament stabilizer which T shaped wings of the implant placed horizontally along the joint and prevent the migration of proximal metacarpal. The wings of the implant are fixed by cortical screws.

From different studies about this implant the degradation caused hydrolysis of Artelon implant after 6 years [7; 57; 67]. During hydrolysis degradation of Artelon, the mechanical properties and the weight of the material were decreased. It should be emphasized that even after hydrolysis degradation of the implant; half of the material (50%) will still remain in the site of implantation [67]. Figures 3.22 and 3.23 are showing the Artelon implant.

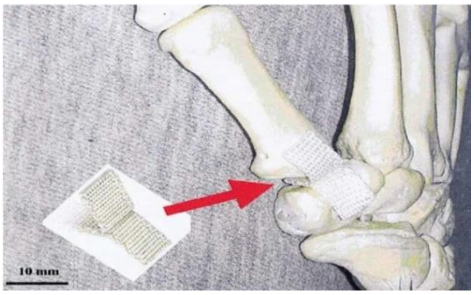


Figure 3.22. *Artelon implant with T shape located as a joint interposition in thump basement and ligament stabilizer, Bar =10 mm [7; 67].*

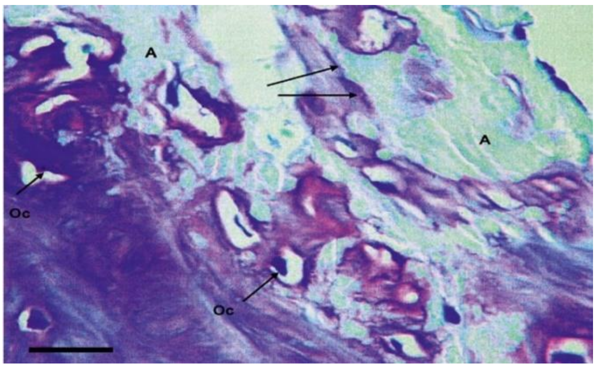


***Figure 3.23**. Artelon implantation after 6 months, (A) artelon (light areas) incorporated in the host bone. Osteocytes (OC) are surrounding the material with a close contact [68].*

Graft Jacket (Acellular Dermal Allograft)

Acellular dermal allografts are received from the human skin [68]. Adams and colleagues have described a technique of interposition arthroplasty of the trapeziometacarpal joint for patients with stage II and III diseases. They interposed a commercially available acellular dermal matrix allograft (GRAFT JACKET) between the arthritic metacarpal base and the distal trapezium bone. From their results, 94% of patients were partialy or compeltely satisfied up to 12 months follow-up time [69].

Trapeziectomy with interposition arthroplasty using an acellular dermal allograft is highly effective for the treatment of thumb carpometacarpal arthritis. Zinon and co-workers were claimed that this procedure can be done for patients with symptomatic Eaton stages II, III and also IV thumb CMC joint arthritis. The acellular dermal allograft procedure can be obtained from figure 3.24.

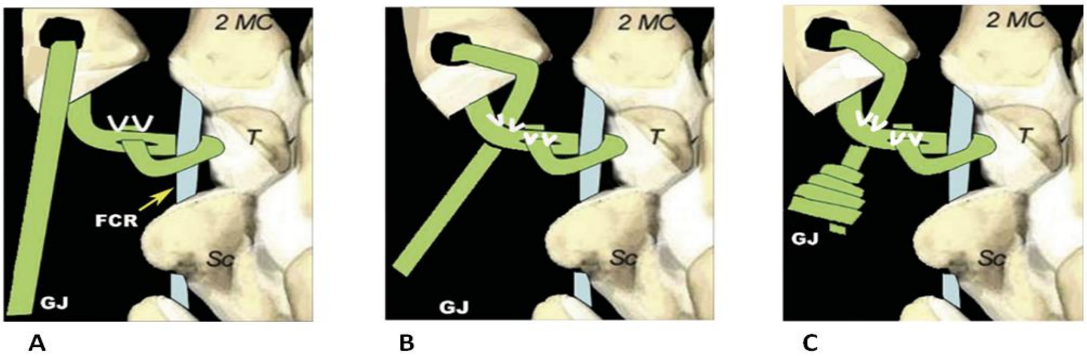


Figure 3.24. *Acellular dermal allograft procedure, (GJ: Graft Jacket, 2MC: Second metacarpal, T: Trapezoid, Sc: Scaphoid) A. The acellular dermal allograft is passed around the FCR tendon and is sutured to itself. The other side is passed through the hole of the base of the thumb, B. The GJ which was passed through the hole of the thumb basement is folded back on itself. C. The remaing portion of the acellular dermal allograft was interposed as an anchovy in the space previously occupied by the trapezium [70].*

Graft jacket procedures do not need K-wire for stabilization and the average time of the procedure was about 35 minutes. Recent results about acellular dermal allograft interposition reported that, there were no foreign body reactions or complications and also no postoperative infections. However a longer follow up, more than 12 months is needed for evaluating this method [70].

3.5 Surgical Techniques

3.5.1 Patient Assessment

In patient assessment, patient´s thumb interphalangeal joint-metacarpophalangeal joint and distal interphalangeal joint should be evaluated. Before and after surgery; pain level, grip strength, key pinch strength and movement were measured for all patients. Grip strength was measured using a Jamar dynamometer and key pinch strength was measured using a Jamar pinch gauge. Radial abduction and palmar abduction were measured using a standard goniometer. Abduction, extension and opposition of the TMJ were measured by the distance between the thumb and palmar crease [42]. Figure 3.25.

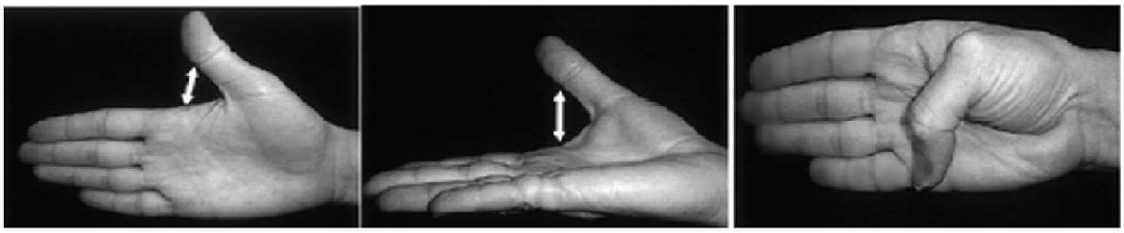


***Figure 3.25**. Methods for measuring TMC extension, abduction and opposition [42].*

Grip strength, thumb pinch and key strengths were measured by using dynamometer and pinch meter. Measuring the distance between the base of the thumb and distal end of the scaphoid (SMD) can determine the height differentiation of the thumb, figure 3.26. By comparison of the pre and postoperative SMD values the shortening of the thumb can be estimated.

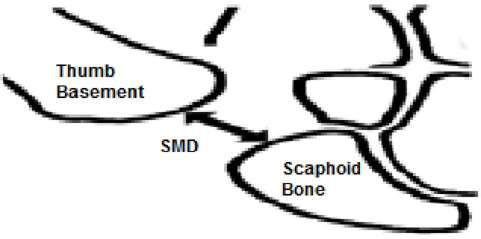


***Figure 3.26.** Standard mean differences (SMD), between distal end of scaphoid and base of thumb [42].*

Hand Dynamometer

Dynamometer has been developed for the assessments of hand muscle strength. In clinical tests which based on patients with hand problems, hand or muscle strengths are measured by grip strength and pinch strength dynamometry [74]. The most commonly used grip and pinch dynamometers are the Jamar dynamometers, figure 3.27.

***Figure 3.27**. Jamar Hand Dynometer [75].*

Pinch Strength

Grip and pinch strength are measured the intrinsic and extrinsic of the hand muscles and joints. Pinch strength mainly evaluates the pinch force of the joints and tendons which are maintioned on figure 3.6. This test, figure 3.28, is used in combination with hand dynometer for providing the definit data of hand strength [40; 74].

***Figure 3.28**. Pinch strength measurement [75].*

Thumb pinch test were done before and after the surgery and by comparing the datas, the strength of the operated thumb can be estimated. Researchers were resulted that, the thumb pinch strength increased after the surgery [40].

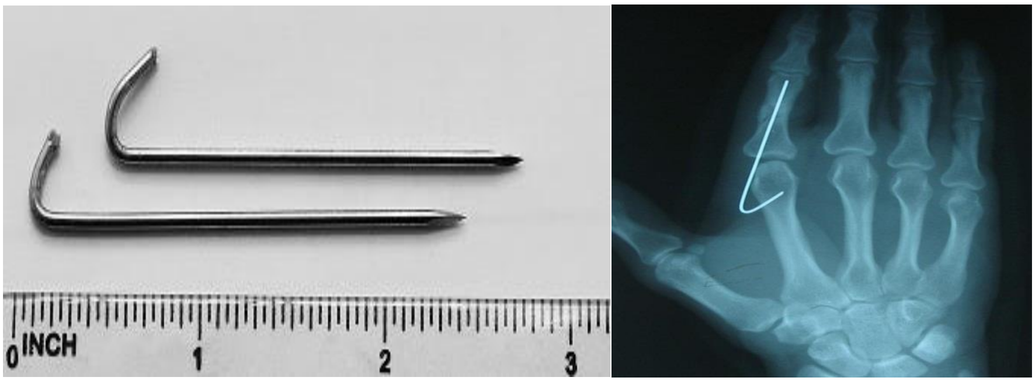
3.5.2 Surgery

The aims of surgical treatment of the rheumatoid arthritis are; pain relief, restoration of function, correction of deformaties and also to create a stable joint by removing the painful osteoarthritis surfaces and allowing the ingrowth of fibrous tissue.This creates an artificial joint that allows motion without painful impaction between two bony surfaces. This is termed to “arthroplasty”.

Surgery is performed under regional anesthesia and a pneumatic tourniquet is used on the arm. The excision of trapezium bone can be done by incision of the dorsal approach in all cases for treatmenting of trapezoid bone failure [47]. The ligament reconstruction by tendon can be surgired by FCR tendon. First FCR tendon harvested and brought out through the trapezial space. The other half of FCR was tunneled through the base of the thumb metacarpal and sutured onto itself. In biomaterial surgery, implant size is an important object for fitting to trapezium bone. Then the implant was placed and the FCR tendon looped and sutured around the implant for increasing the stability [40].

3.5.3 Experimental treatment

Kirschner wire (K-wire) is used to stabilize the joints after the arthroplasty and maintain the scaphometacarpal space. K-wire fixation should be remained for 8 weeks, figure 3.29, and it can be removed after 3-4 weeks. The range of the motion exercises can be allowed to the patients after resection of k-wire.



Figute 3.29. *Kirschner wire (K-wire) [71].*

Recently Mersilene suspension suture is also used for stabilizing the thumb after resection of the trapezium bone [72]. Mersilene is a non-absorbable woven polyester fiber suture. The suture is double-ended with blunt semicircular needles and a 12 inch polyester ribbon [73], which can be seen in figure 3.30.

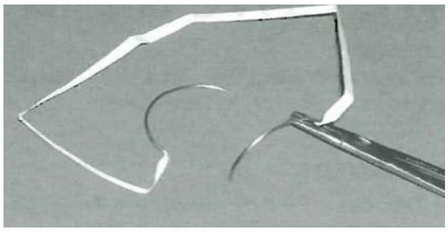


Figure 3.30. *Mersilene Suspension Sling [73].*

The goal of this procedure is to attach the base of the first metacarpal to the base of the second metacarpal, so the proximal migration of the first metacarpal will be prevented by the stability of the second metacarpal. Figure 3.31 is showing the skeleton model of completed Mersilene suspension. The suture passes around the base of the second metacarpal and around to non bony part of the first metacarpal [73].

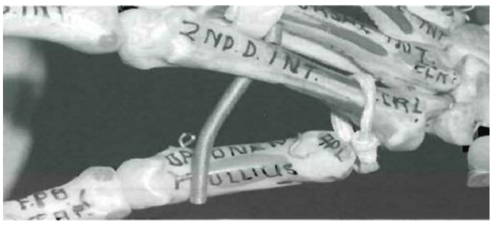


Figure 3.31*. Mersilene suspension suture around the base of the second metacarpal and non bony part of the first metacarpal [73].*

Mersilene sling suspension is a simple procedure that does not need postoperative surgery. Marwan and co-workers claimed that, it does not require any expensive materials and it can be completed with in 90 minutes and in addition the grip and pinch strength are also improved after the surgery.

Mini TightRope is a device that used for the CMC arthritis patients. It made up of two Titanium bottoms and a wire which is folded together. Mini TightRope promotes new ligament formation between first and second metacarpal and also prevents migration of the first metcarpal. This device also enables good connective tissue formation between bones. Mini TightRope is produced by Arthrex, a company which manufactures orthopedic surgical supplies [85]. This device can be seen from figure 3.32.

Figure 3.32. *Mini TightRope [85]*.

3.5.4 Post operative treatment

The sutures were removed after 2 weeks and a splint should be worn for 6 weeks. After 10 days of surgical treatment, therapy is started. Several studies have indicated that this treatment have shown 95 % of success in the patients and also regeneration of thumb funcations. Different tests are reported for evaluating the ability of hand motions such as “Box and Block” and ADL (activities of daily living) tests [59; 60].

4. RESULTS

4.1 Treatments of Trapeziometacarpal joint arthritis

There are various equipment and tests for comparing the different treatments of TMC arthroplasty. Recent studies were shown student´s t-test for comparing the preoperative and postoperative values and also pinch and grip strength tests [59].
Recent studies have been shown that, the fusion group had a higher complications rate than the excision and silastic replacement group. The main problem of the total fusion is the loss of motion of the wrist joint. Excision treatment did not report any complications. Taylor claims that silastic replacement produced more flexion than fusion treatment. However in long term results, silastic replacement has shown high rates of osteolysis and synovitis. Excision of trapezium bone reported good long term results without complications. Compared to the silastic replacement and fusion treatment, Taylor and co-workers recommended excision treatment with or without soft tissue reconstruction for middle aged and elderly patients [3].

Excision of the trapezium bone with ligament reconstruction with or without tendon interposition is the commonly treatment for trapeziometacarpal osteoarthritis, however Gangopadhyay and coworkers indicated that there are no benefits to tendon interposition or ligament reconstruction in long time. Furthermore, they suggested that the use of additional soft tissue was not harmful but it is also not necessary for long time [47].
Belcher and Nicholl studied the comparison of simple trapeziectomy combined with PL (Palmaris longus) tendon interposition or LRTI (Ligament reconstruction and tendon interposition) using the FCR tendon. They also found no significant difference between these methods [42]. From the comparison of the trapeziectomy and trapeziectomy with LRTI, trapeziectomy resulted in higher strength than LRTI treatment. Consequently from the above results it can be concluded, however after trapeziectomy the shortening of the thumb can be observed but LRTI and restoration of trapezial space does not prevent this situation.

From various studies [3; 40; 42; 76] the researchers found out the results of simple excision of the trapezium are similar to those produced by excision of trapezium by ligament reconstruction and tendon interposition. Comparison between silicone implant treatment with ligament reconstruction and tendon interposition (LRTI) was done by Luria and co-workers on 2007. They concluded that the biomechanical behaviours of silicone implant such as reduction in axial and radial displacement and protection of trapezium space was more optimal than LRTI treatment [40].

4.2 Implants for Trapezium bone failure

The main disadvantage of any resection treatment is the weakness of the thumb pinch strength. However from recent studies; partial trapezial resection has shown less of weak pinch strength by protecting more of the trapezium bone.

Investigators concluded that there is no significant difference between silicone arthroplasty and LRTI treatment in range of motion after surgery. However silicone implant had decreased displacement and better filled trapezial space compared to LRTI treatment. The comparison between LRTI and Artelon implant indicated that, lower grip, lower pinch strength, pain and swelling were more common in Artelon treatment than LRTI treatment. Titanium arthroplasty was also compared to LRTI treatment; researchers found out high failure rate in titanium arthroplasty than LRTI. The Elektra prosthesis which uses ball and socket metallic implant was compared to APL tendon interposition, from the results the total joint arthroplasty had better pain relief, grip strength and range of motion than APL tendon treatment.

Prosthetic replacement arthroplasty of the trapezium bone were compared. Silicone prosthetic trapezial spacer can be treated in low demands rheumatoid patients. However this material causes silicone synovitis, implant failure and loosening. Artelon interposition implant also was not suggested by investigators for treatment of TMC joint. Metallic implants had failures related to the significant forces across the base of the thumb. Gortex implant showed more pain and osteolysis compared to ECRL treatment.

Investigators compared the PLDLA implant with silicon Swanson implant, although they did not find any main difference in hand strength tests (grip test, pinch test, Box and Block test), but there was palmar subluxation in PLDLA implant. However implant fracture was observed more in silicon Swanson than PLDLA implant. Nilsson and co workers compared Artelon implant with APL tendon arthroplasty; they were found better pinch strength after surgery in Artelon implant compared to tendon arthroplasty and there was no difference in the range of motions of the hand after procedure [67]. Researchers conclude that the newer joint implants may have a better outcome than trapeziectomy with LRTI [59; 70]. Table 4.1 is showing the main differences of trapezium bone arthritis treatments.

Table 4.1. *Main Property Comparison of trapezium bone treatments*

Properties	Fusion	Trapeziec-tomy (Excision)	LRTI	Silicone Implant	Artelon Implant	Metallic Implant	PLDLA Implant
Damage	Yes	No	No	Yes	Yes	Yes	No
Infection	Yes	No	No	Yes	Yes	Yes	Yes
Reoperation	Yes	No	No	Yes	Yes	Yes	No
Flexion	No	Yes	Yes	Yes	Yes	No	Yes
Strength	Yes	Yes	Yes	No	Yes	No	Yes

4.3 Clinical tests

From recent studies [40; 47], there are no significant difference between the clinical tests and all types of surgery can improve the key and tip pinch strength. From study of Gangopadhyay and co-workers the normal thumb considered more stonger than operated thumb, but after 5 years the strength observed similar in both thumbs. Table 4.2 is showing the results of pinch and grip strength befor and after the operation, which was done by Gangopadhyay and co-workers in 2012.

Table 4.2. *Comparison of thumb strength before and after operation [47].*

Test		before	after	% change
Pinch Strength	Operated thumb	7.4 ± 3.3	10.6 ±3.4	+43%
	None operated thumb	11.5 ±4.8	10.5 ± 3.9	-10%
Grip Strength	Operated thumb	28.3 ±12.5	36.0 ± 13.1	+27%
	None operated thumb	36.2 ±11.9	35.2 ± 15.7	-2.8%

Recent studies concluded that, there are no statistically significant differences in postoperative between grip strength, tip pinch strength and key pinch strength.

4.4 Meeting with Dr.Jarkko Vasenius, Hand surgeon

Professor Jarkko Vasenius is working as a hand surgery specialist doctor at Omasairaala Hospital , Helsinki [87].The hand surgey questioner in Appendix 1, was discussed with him on 4.09.2013. He currently uses trapeziectomy technique with mini TightRope device by arthroscopy technique in treating patients suffering from osteoarthritis in thumb basement. However, the thumb becomes weaker and shorter by this treatment method. Dr. Vasenius maintained that he applied artelon and pyrocarbon implants on his patients. Artelon implant results in tissue reaction and non flexible behaviour in thumb basement. Since pyrocarbon is non-stable and large implant, it causes dislocation in thumb area. He applies arthrodesis (fusion) treatmet method to young patients who have more activity. For elderly patients he suggested trapeziectomy treatment. This treatment is also cheaper than arthroplasty method. He also used PLDLA implant in animal tests and longer-time results are needed for this implant.

In terms of future prospects, he suggested that safe biodegradable implants which can be replaced by fibrous tissue would be the best choice for future. This kind of implants should not have any infections in the body to prevent reoperation. Biodegradable implant will be also good option for young patients.

5. DISCUSSION

Small joints of the hand and foot are affected by the rheumatoid arthritis and osteoarthritis. There are several methods and surgeries which can be applied for confronting RA and OA diseases. This study is focused on the treatments of trapezium bone failures by hand arthritis. Trapezium bone is located in the base of the thumb. Arthritis at the base of the thumb is a common problem these days. For this reason several studies were discussed about the therapeutics of the basal joint arthritis. Trapeziectomy, LRTI with or with out tendon interposition and arthroplasty are the common treatment methods. This thesis introduced the biomaterials that can replace with trapezium bone. Comparing various techniques is difficult for many reasons. Pain and activity level are difficult to compare from one study to another because of patient variables such as personality, activity level in hobbies and work, especially in an older population. Furthermore, most studies have a short follow-up (avarage 12 months) and do not demonstrate any advantage of one procedure over others.

Simple excision of the trapezium bone was described by Grevis in 1949 [68; 88], by observing some complications, Swanson introduced silicone interposition arthroplasty in 1968 [69; 70]. After wide range of experiments, this material was reported implant instability, cracks snd silicone synovitis. Eaton and Littler [77], Burton and Pellegrini [78] and Weilby [79], were also investigated tendon ligament reconstruction by using tendon grafts. Many variations of that procedure were reported, with or without tendon interposition and all seems have similar results. Technical treatments except implant replacement were discussed in several studies. Trapeziectomy (T) is an effective operation for osteoarthritis at the base of the thumb [42]. This treatment can be done by ligament reconstruction and tendon interposition (LRTI). LRTI is one of the most common surgical treatment option in trapezium excision. Trapeziectomy with ligament reconstruction with or without tendon interposition has been shown to be highly effective in the treatment of thumb CMC joint arthritis [91; 92].

Several tendons have been used for this procedure. The tendons were applied mainly in ligament reconstruction and tendon interposition (LRTI) function are; abductor pollicis longus (APL), Extensor carpi radialis longus (ECRL) and Flexor carpi radialis (FCR). FCR tendon is the most commonly used autograft [52; 70]. Trapeziectomy with APL tendon interposition arthroplasty for moderate the CMC arthritis provided good long term results. The main advantage of APL tendon is, that is generally comprised of multiple tendons.

FCR tendon compared to APL tendon has lower flexion-to-extension peak torque ratio and also FCR tendon interposition arthroplasty is technically more difficult to perform with longer surgery times [80]. ECRL can be used instead of FCR, when a palmar approach is difficult for repeating surgeries. ECRL tendon resulted in good thumb motion. However harvesting of ECRL tendon is more difficult than FCR [49]. The procedure of applying trapeziectomy to trapezium bone can be done by total resection of trapezium bone (total trapeziectomy) or partial trapeziectomy. Total trapeziectomy or resection of trapezium bone was not recommended by most researchers. They concluded that, LRTI-PT (partial trapeziectomy with ligament reconstruction and tendon interposition) offer better possibilities than LRTI-TT (total trapeziectomy with ligament reconstruction and tendon interposition) [44].

Different results were reported about comparison between the excision of trapezium bone and LRTI treatment. Hollevoet reported that, the group of patients with ligament reconstruction and/or soft tissue interposition tended to have better subjective results than the groups without soft tissue interposition or simple excision of trapezium. He also noted that, the patients with ligament reconstruction had better results [78]. Hofmeister also described that, one of the most common surgical treatment option is trapezium excision with a ligament reconstruction and tendon interposition (LRTI) [67]. However Gangopadhyay [47] and Ebelin [81] claimed that there was no difference in the pain relief achieved in treatments. Grip strength and key and pinch strength did not differ among the 2 groups. They also concluded that, there is no benefit to tendon interposition or ligament reconstruction (LRTI) after the excision of the trapezium bone. Since trapeziectomy is simple and rapid whereas, ligament reconstruction and tendon interposition (LRTI) resulted in longer operation and stabilizing procedures can be suitable when there is significiant subluaxation and instability at the TMC (trapeziometacarpal) joint. Researchers reported that DASH and PEM scores and also key and tip thumb pinch and all other clinical measurments did not differ significiantly between the T+ LRTI and T treatments at either 3 month or 1 year after surgery [42; 76; 83].On the other hand, Naidu and co workers [83] reported the effects of harvesting the entire FCR tendon. They concluded that, the potential infections can be observed from the harvesting of an autograft. For these reason alternative materials have been used for thumb CMC joint arthroplasty.

Recently available materials were viewed by Birman and Strauch [84]. The main goals of a joint replacement are to eliminate the pain, providing stability, restoring mobility and long implantation time as well [4]. The placement of an artificial joint for showing proper rotation is dependent on: proper design of the prosthesis to place in the center of rotation - articular component should be relative to the stem-accurate placement of the prosthetic stem within the bony canal, and selection of a prosthetic size compatible with the joint size [5].

Arthroplasty with silicone rubber implants is an excellent treatment of inflammatory diseases of hand [65]. It is mainly used in finger joints, carpal bones and etc. [4]. The main advantages of silicon are providing mobility and stability, the shape of the implant can also change from a convex to concave surface. Silicone rubber implant also has some complications such as implant subluxation and silicone synovitis, which may be avoided by proper techniques [58]. Luria and co-workers claimed that, the implant arthroplasty resulted better biomechanical treatments compared to trapeziectomy, LRTI, TI and LR [40; 89; 90].

The long-term results of trapeziometacarpal silicone arthroplasty showed that, silicone trapezium implants had better strength and stability than trapezium excision. Trapeziometacarpal joint silicone arthroplasty seems to provide good, long-term patient satisfaction and improved function with a low complication rate [59]. Silicone replacement also produced more flexion than fusion treatment, however it has shown high rates of wear and synovitis in the long time [3]. Another material has also been used for the trapezium replacement, such as metallic implant, Artelon, Pyrocarbon and PLDLA. Recent studies compared the main challenges of these implants. Metallic implant was reported to result in loosening of the implant and significiant forces across the base of the thumb [7; 57]. Pyrocarbon implant is mostly used in radiocarpal and midcarpal wrist joints such as; lunate, two thirds of the scaphoid and capitate head. Future research is needed to determine the long-term outcomes of the latest generation of pyrolytic carbon prostheses [7]. Artelon is a biodegradable polyurethane implant that offers an ideal interposition material. This implant showed significianlty better pinch strength after Artelon TMC spacer implantation compared with APL (abductor pollicis longus) tendon arthroplasty [67]. However this implant compared to LRTI and trapeziectomy treatment reported poor quality and also reactions of the body to this implant was observed [7]. Due to the mechanical failure in Artelon implant, other material such as acellular dermal allograft was tested. Acellular dermal allograft can be used safely and successfully for the treatment of thumb CMC joint arthroplasty. This material was followed up for 12 months and larger experiments will be necessary to assess the definitive validity of this method [70].

The comparison between PLDLA and silicone implant was reported. From the recent studies which were obtain in Tampere Technical University, PLDLA implant did not result in any fractures, however Swanson implant can be resulted better palmar arrangement than PLDLA implant. No differences were noted in ROM and stability between PLDLA and silicone Swanson groups and the clinical outcomes were quite similar at 24 months of follow-up. PLDLA implant in comparison to tendon interposition arthroplasty treatment reported easier procedure, good pain relief and also the range of motion in two groups was similar. PLDLA implant compared to Artelon implant, had no foreign body reactions.

Further studies with larger patients and longer follow-ups are needed for PLDLA implant, before this method can be widely recommended [60; 64; 65; 66].

CONCLUSION

Comprehensive reviews of trapezium treatments conclude that, no technique is superior to others and most have some successes and drawbacks.

The most problem for replacing the artificial joint in rheumatoid arthritis was the difficulty in restoring soft tissue balance. Several implants have been reported for rheumatoid arthritis. Swanson imlant is still considered as the gold standard for MCP joints replacement in rheumatoid arthritis, however implant fracture is an evident problem of silicone implants arthroplasty after long time in CMC joints. For this reason several material were evaluated for thumb basement arthritis. PLDLA implant is considered as a biodegradable implant which can be replaced with fibrous tissue in 2-3 years. PLDLA interposition surgery is faster than LRTI method. The palmar subluxation of PLDLA is the main challenge of this implant compared to silicone elastomers. PLDLA and acellular dermal allograft needed longer follow-up for recommending these implants for rheumatoid arthritis patients.

Although the ideal implant may not be currently available, future steps can be improved in any joint replacement of TMC joint. The future designs should permit essential functional range of motion by higher joint stability or durability and implants demanded long-term stability with less bone reaction.

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8. APPENDIX

8.1 Appendix 1: Hand Surgery Questioner

TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

1. Which implants are you using in patients with hand diseases?

2. What are the main advantages of that implant?

3. What are the main materials of implant?

4. What are the main challenges of using the implant in surgery?

   Size:
   Shape:
   Infection:
   Rejection:
   Flexibility and strength:

Figure 8.1. *Hand Surgery Questioner, Page 1.*

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5. What are the main problems of the patients after the surgery? (Infection- Life t)

Infections:

Life time of Implant:

Loosening of the Implant:

6. Do you have any suggestions for improving the implant?

Best regards

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Master thesis: Implants of Small joints in Hand

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Figure 8.2. *Hand Surgery Questioner Page 2.*