DESSERTATION ON

MANAGEMENT OF PROXIMAL PHALANGEAL FRACTURES OF HAND: ROLE OF LONG ALUMINIUM SPLINT IMMOBILIZATION

DEPARTMENT OF PLASTIC SURGERY,
INSTITUTE OF RESEARCH AND REHABILITAION OF HAND,
GOVT. STANLEY MEDICAL COLLEGE
CHENNAI 600001

THE TAMILNADU DR. M.G.R. MEDICAL UNIVERSITY
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CERTIFICATE

Certified that this dissertation on **MANAGEMENT OF PROXIMAL PHALANGEAL FRACTURES OF HAND: ROLE OF LONG ALUMINIUM SPLINT IMMOBILIZATION** submitted by ***Dr. M.S.Viswanathan,*** who is appearing for M.Ch (Plastic surgery) examination in February 2006, is a bonafide record of original work done by him under my direct guidance and supervision.

Prof. T.C. CHANDRAN, M.S, M.Ch
Professor and Head of Department of Plastic and Reconstructive surgery, Institute of Research and Rehabilitation of Hand.
Govt. Stanley Medical College
Chennai

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Last but not the least I thank all our patients and their relatives without whose cooperation this study could not have been completed.

CONTENTS

INTRODUCTION

Phalangeal fractures are the most common fractures of upper extremities. It accounts for approximately 1/3 of fractures involving the hand.

Outer rays of hand especially thumb and little fingers are most commonly involved. These are often neglected or regarded as trivial injuries.

"Hand fractures can be complicated by deformity from no treatment, stiffness from over treatment, both deformity and stiffness from poor treatment."

-Swanson

This aphorism is true and must the always kept in mind while treating these fractures

In our country where in population is high, and working class is employed in industries with minimal or no protective measures and poor working environment, the incidence of these injuries are high. Losses resulting from these in terms of days of restricted activity and days off work are very significant.

Success of management depends on the type of fracture, good patient motivation apart from surgical skill. Goal of treatment is to have full and rapid restoration of function.

Incidence of these fractures is so high, and disability resulting from it so crippling if improperly managed, inspired this study.

AIMS OF THE STUDY

1. **To study the Epidemiology of proximal phalangeal fractures.**
2. **To review various modalities of management of proximal phalangeal fractures as practiced in our Institute**
3. **Evaluate the results of proximal phalangeal fractures management**
4. **Compare the Functional outcome of Long Aluminium Splint Immobilization of these fractures as compared with other modalities**

MATERIALS AND METHODS

This study consists of evaluation of all proximal phalanx fractures seen in our department for 1 year from March 2004 to March 2005. (Replantation through proximal phalanx were not included).

This combined prospective & retrospective study included analysis of age, sex, nature of injury socioeconomic status, number of fingers injured, ray involved, type of fracture, associated injuries to adjacent structures, pre and post operative x-rays, type of fracture fixation, evaluation of post operative results and management of secondary complications.

Patients were followed up after a period of 3 months. Evaluation of results was done using criteria proposed by ***Buchler et. al. (1996).***

PROTOCOL OF MANAGEMENT

The various methods adopted for management of cases are techniques used in our institute

INDICATION FOR CONSERVATIVE TREATMENT

This consists of closed reduction and POP immobilization. Indications are:

1. Undisplaced intra or extraarticular fractures stable after reduction
2. Severe injuries with doubtfully viable fingers
3. Severe comminuted fracture

INDICATION FOR LONG ALUMINIUM SPLINT IMMOBILIZATION (L.A.S.I)

1. Simple fracture transverse or oblique of shaft or base of proximal phalanx
2. Compound noncomminuted fracture involving single finger
3. Selected intraarticular fractures with severe communion.

INDICATION FOR K-WIRE FIXATION OR S.S.WIRE FIXATON

1. Irreducible fractures
2. Malrotation (spiral and short oblique)
3. Intraarticular fractures
4. Subcapital fractures
5. Open fractures
6. Segmental bone loss (K-wire spacer)
7. Polytrauma with hand fractures
8. Multiple hand or wrist fractures
9. Fracture with soft-tissue injury (vessel, tendon, nerve, skin)

ANESTHESIA

All our cases were managed by regional anesthesia **- Axillary** block (mostly) or **Supraclavicular** block. We use 0.25% Bupivacaine with 1% Xylocaine in 30 ml as standard, calculated as per requirements of body weight.

TECHNIQUE USED

1. CLOSED REDUCTION WITH POP IMMOBILIZATION
2. CLOSED REDUCTION WITH LONG ALUMINIUM SPLINT IMMOBILIZATION
3. OPEN REDUCTION WITH K WIRE FIXATION
4. S.S.WIRE FIXATION

Our technique of closed reduction, open reduction with K-wire / SS wire fixation is no different from that described as standard technique.

However the **Long Aluminium Splint Immobilization developed** in our institute is unique and has been practiced for several years with successful outcome.

METHOD OF LONG ALUMINIUM SPLINT IMMOBILIZATION

Under regional block anesthesia, 2-0 Prolene (Polypropylene) nail stitch is taken and kept ready for each of the involved finger (we have used for all of 4 fingers excluding thumb). A long Aluminium splint of 50 cm length and 2 cm width is taken and is moulded to the required shape on corresponding finger of opposite normal hand. This is done by leaving 10 cm length of splint at distal end, the remaining splint is bent at wrist 30 deg dorsiflexion, MP joint in 90 deg flexion and IP joints fully extended. The distal 10 cm is bent back in itself to serve as anchor for the prolene stitch from nail plate. This splint is incorporated in 2 layers of POP applied from distal palmar crease to below elbow (volar BE slab) and POP is allowed to harden (set). Finger is flexed at MP joint over the splint and traction applied and fracture reduced. Nail stitch is used to maintain reduction. Retaining this tension in the prolene wire it is tied to distal end of the splint maintaining the reduction. Small adhesive plaster pieces are used to prevent the knots from slipping. Protective plasters are applied over the splint to prevent inadvertent injuries.

Check x-rays are taken and studied for accuracy of reduction. If reduction found inadequate or if there is too much distraction of fragments finger is manipulated or the tension on thread reduced by bending the splint further. Reduction is again confirmed by x-ray.

Patients are followed up as outpatient on 2nd post operative day and then every week and splint position checked. X-Rays are taken if needed

POST OPERATIVE IMMOBILIZATION & REHABILITATION REGIMEN FOLLOWED IN THIS STUDY

Hand is immobilized in below elbow volar POP slab in conservative as well as K-wire or SS Wire fixation. Wrist kept in 30 deg dorsiflexion, MP joint in 90 deg flexion, and IP joints straight. This immobilization is maintained for 3 weeks following which POP or LASI is discarded and active mobilization started. Further 3 weeks later active mobilization is combined with passive immobilization.

PROFORMA FOR EVALUATION OF PHALANGEAL FRACTURES
PROF. T.C.C UNIT

Name: **Age**: **Sex**: **Ps. No**:
Address: **Date of injury**:

Side: R / L / Bi **Force: Crush / Sharp / Blunt / Blast**

# site	**Ray**					
	Bone					
	Site					
# Parti culars	**Simp/com**					
	Type					
	Stable					
	Articular					
	Bone loss					
	Displace					
Conse rvative	**Al. splint**					
	Moulding					
	None					
K-wire	**Numbers**					
	Placement					
S.S. wire	**Sq knot**					
	Fig.of 8					
A.O	**Plate**					
	Screws					
Skin	**Loss**					
	Repair					
Flexors	**Level**					
	Repair					
Exten sors	**Level**					
	Repair					
Vessels	**Level**					
	Repair					
Nerve	**level**					
	repair					

Splint Removal:

Skin: Edema / Primary Healing / Secondary Healing / Flap settled- partial-complete

Sensation: Intact / Blunted / Lost

Distal finger: Lost / Ischemic / Normal

Bone: Malunion / Nonunion / Sequestrum

Tendon & Joint:

FINGER		**MP**	**PIP**	**DIP**	**MP**	**PIP**	**DIP**	**MP**	**PIP**	**DIP**
	AROM									
	PROM									
	AROM									
	PROM									
	AROM									
	PROM									
	AROM									
	PROM									
	AROM									
	PROM									

Secondary Procedures: Sequestrectomy / Amputation / Tendon Reconstruction /Nerve reconstruction / Fracture refixation Capsulotomy / Tenolysis

RESULT:

1. **Complete correction of pre op deformity**
2. **Full bony union**
3. **No pain**
4. **Patient returned to work**
5. **Patient satisfaction good or above**
6. **No trophic or sensory problems**
7. **No tendon adhesions**
8. **ROM within 10 degrees of full range**
9. **Flexion brings finger tip to within 1 cm of palm**

Points

> 8 = Excellent
7 = Good
5-6 = Fair
< 5 = Poor

RESULTS

Total no of patients	180

Sex

Male	147
Female	21
Child	12

Side

Right	99
Left	81

Force

Crush	147
Sharp	21
Blunt	9
Blast	3

Ray

Thumb	57
Index	57
Middle	15
Ring	18
Little	33

Site

Head	39
Neck	12
Shaft	108
Base	21

Simple	51
Compound	129

Type

Transverse	99
Oblique	61
Spiral	5
Comminuited	15

Stable	33
Unstable	147

Articular

Unicondylar undisplaced	33
Unicondylar displaced	9
Bicondylar	0

Displacement

Angulation	35
Shortening	3
Rotation	24
Mixed	25

Mangement

Conservative	47
LASI	61
K wire	63
SS wire	9
AO	0

k wire

Oblique	62
Transverse	1

SS Wire

Sq.knot	6
Fig. of 8	3

Skin

PSS	119
SSG	7
Flap	3

Income

<1500	108
1500-2500	48
>2500	24

Mode of injury

RTA	44
House hold	40
Industrial	51
Crackers	3
Weight	30
Agicultural	12

Reviewed cases	68		
	Total	Single	Multiple
Conservative	17	11	6
LASI	34	28	6
K wire	15	5	10
SS Wire	2	2	0

Results of management	Conservative		LASI		K Wire		SS wire
	Single	Multiple	Single	Multiple	Single	Multiple	Single
Complete correction of pre op deformity	8	1	25	4	5	9	2
Full bony union	7	5	28	6	5	9	2
No pain	5	2	28	5	5	10	2
Returned to work	5	3	28	6	4	7	1
Patient satisfaction good or above	8	3	28	6	4	8	1
No trophic or sensory changes	10	5	28	6	5	9	2
No tendon adhesions	8	3	28	6	2	5	1
ROM within 10 deg of full range	5	2	25	4	2	5	0
Flexion brings finger tip within 1cm of palm	5	1	25	4	2	6	0

Osteomyelitis	1	1	0	0	0	1	0
Amputation	1	1	0	0	0	1	0
Joint stiffness	2	2	0	0	1	3	0
Tendon Adhesion	3	2	0	0	1	3	0
Ischemic distal finger	3	3	0	0	0	0	0
Malunion	5	4	3	2	0	1	0
Nonunion	1	2	0	0	0	0	0

Gross total

	Conser	LASI	Kwire	SSwire
Complete correction of pre op deformity	3	29	14	2
Full bony union	12	34	14	2
No pain	7	33	15	2
Returned to work	8	34	11	2
Patient satisfaction good or above	11	34	12	2
No trophic or sensory changes	15	34	14	2
No tendon adhesions	11	34	7	1
ROM within 10 deg of full range	7	29	7	1
Flexion brings finger tip within 1cm of palm	6	29	8	1
Osteomyelitis	2	0	1	0
Amputation	2	0	1	0
Joint stiffness	4	0	4	0
Tendon adhesions	5	0	4	0
Ischemic distal finger	6	0	0	0
Malunion	9	5	1	0
Nonunion	3	0	0	0

FINAL EVALUATION OF RESULTS					
Score Points	>8	7	5 to 6	<5	
	Excellent	Good	Fair	Poor	
Conservative	2	7	5	3	17
LASI	29	4	1	0	34
K-wire	9	4	2	2	15
SS Wire	1	1	0	0	2

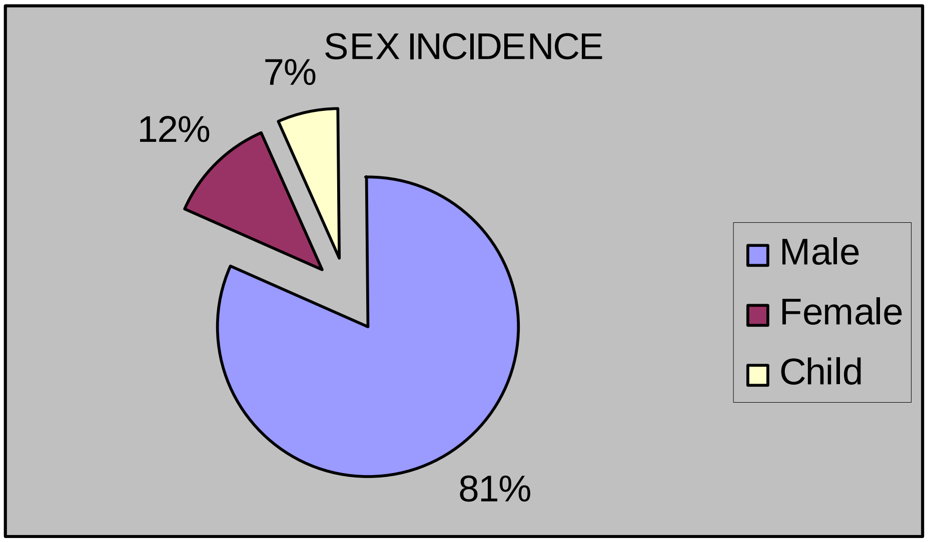
CLINICAL ANALYSIS

The statistical data collected were analyzed with regard to various epidemiological factors as percentile of total; the results of this are presented in charts for easy interpretation.

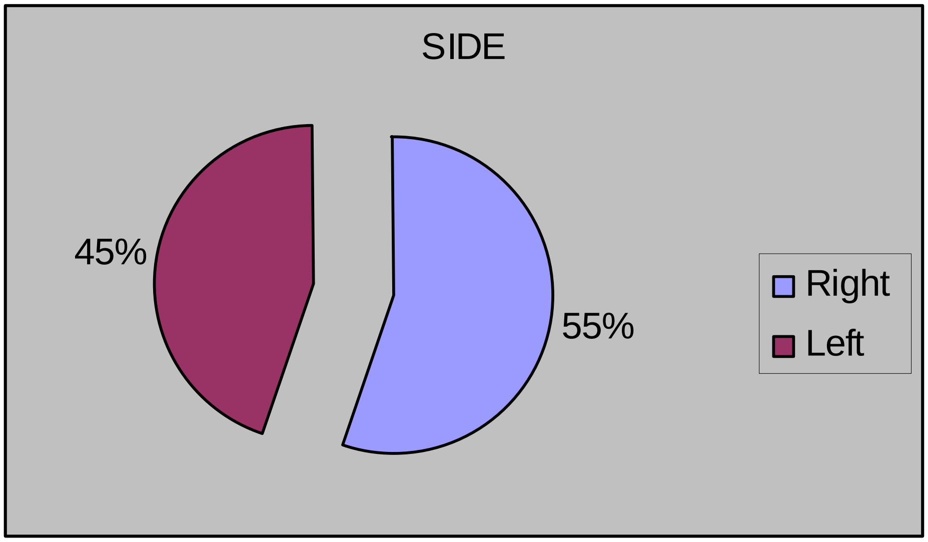
Though we had 180 patients who had undergone treatment in our institute we were able to follow up only 68 patients. The others failed to turn up in spite of repeated reminders by letters.

Proforma developed for evaluation of results is shown in the following page.

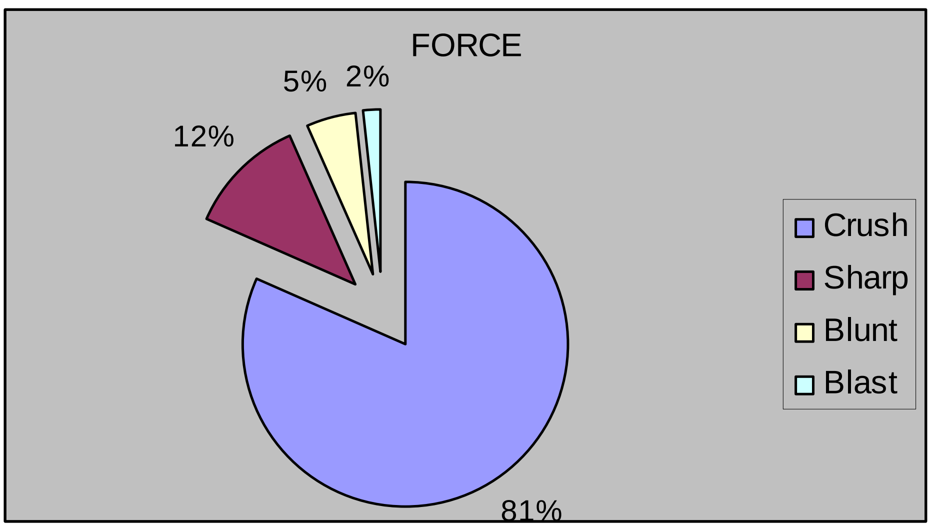
The different management modalities were evaluated at end if 3^{rd} month for its efficacy.



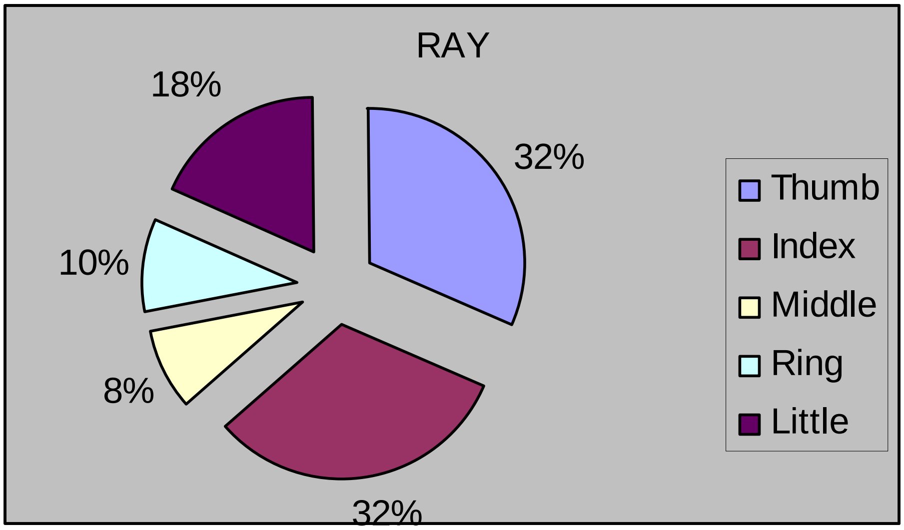
Incidence in male is greater than in females.



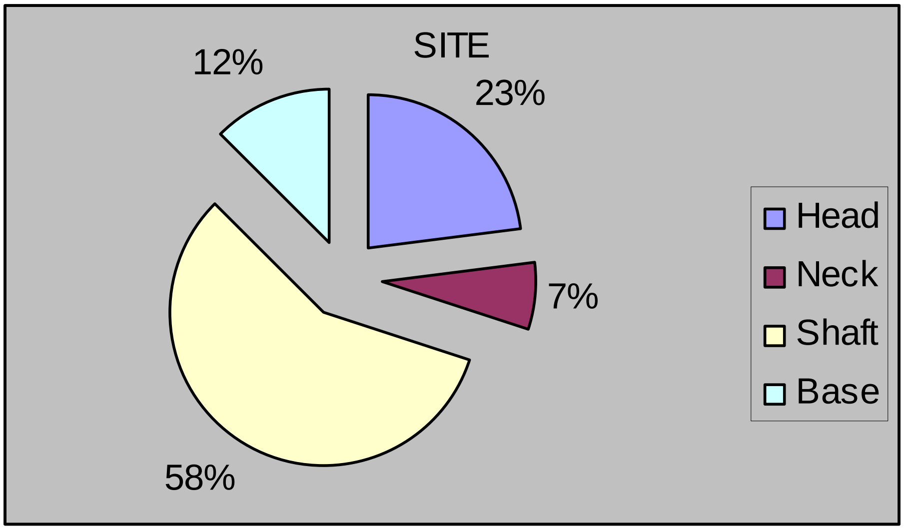
Right side is more frequently involved than left



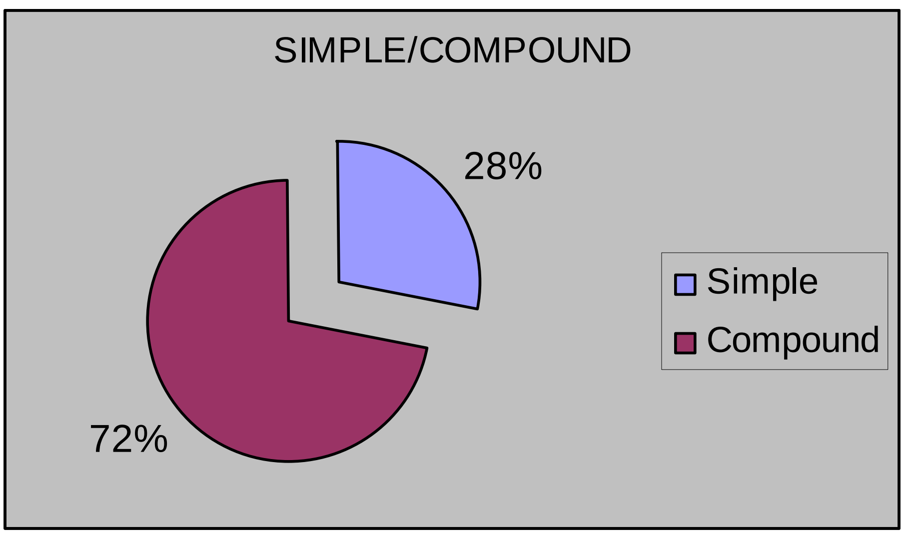
Most frequent force of injury had been crush. Blast injuries had been mostly due to crackers.



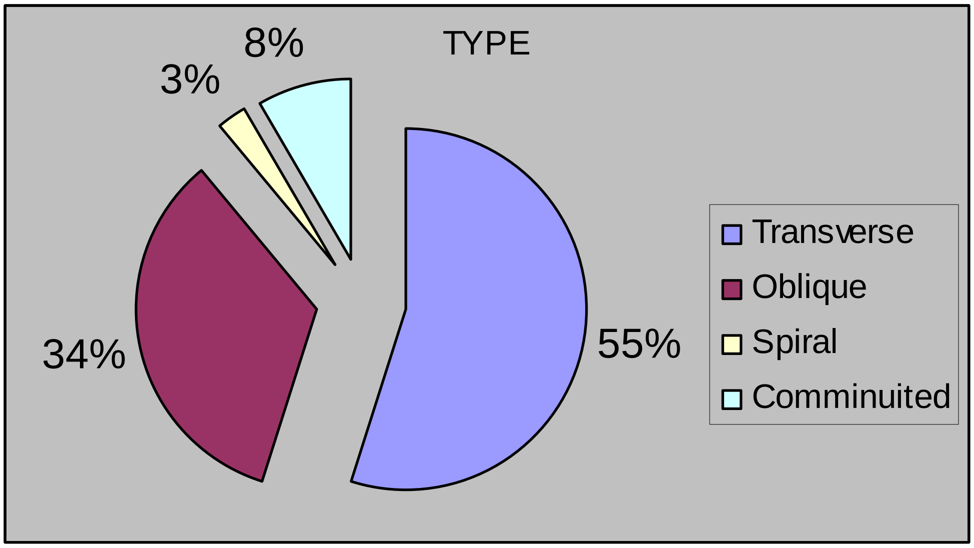
Index and thumb had been most frequently injured fingers. It was followed by little finger. Mid finger is the least involved probably due to its central position.



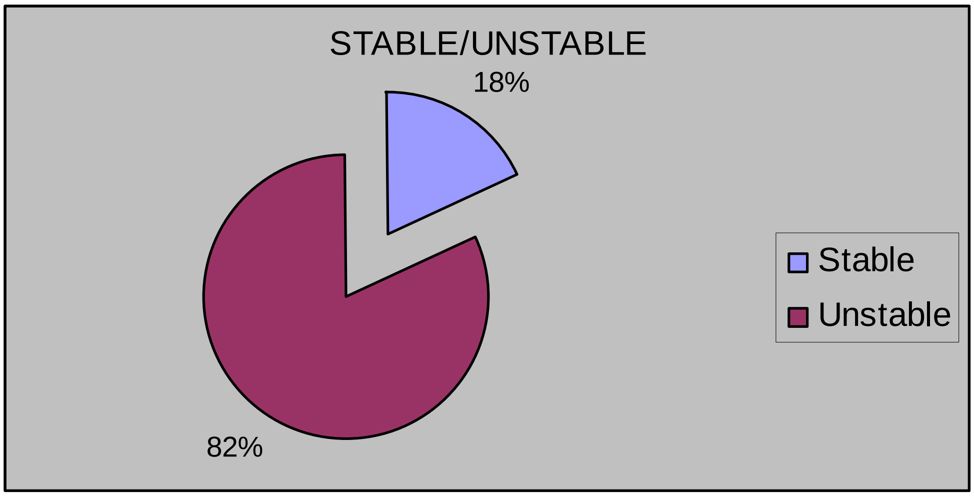
Shaft is the most frequent site involved, followed by head. Neck is the least involved site.



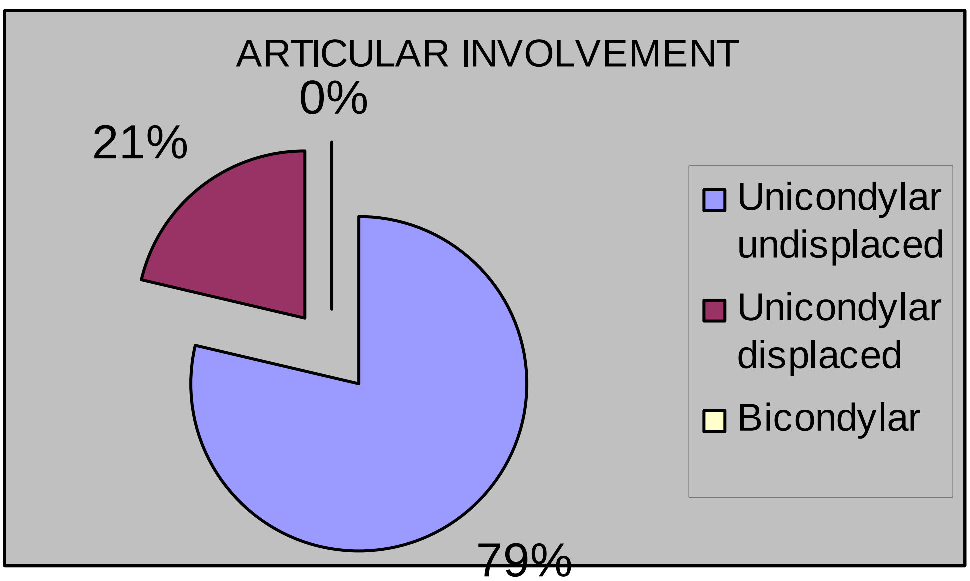
72% of injuries were compound, the rest simple. With proper Debridement most of our compound fractures settled without infection.



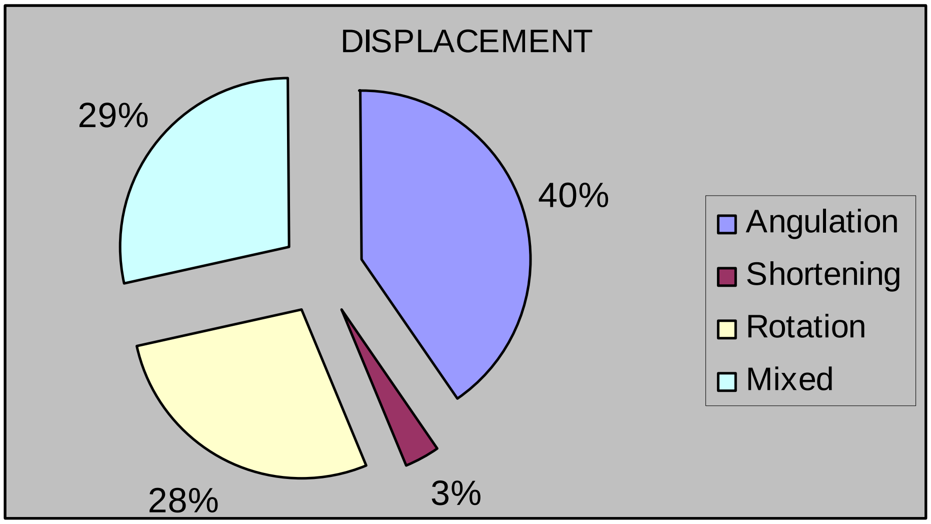
Transverse fractures were the most frequently seen followed by oblique and comminuted. Spiral fractures were least common



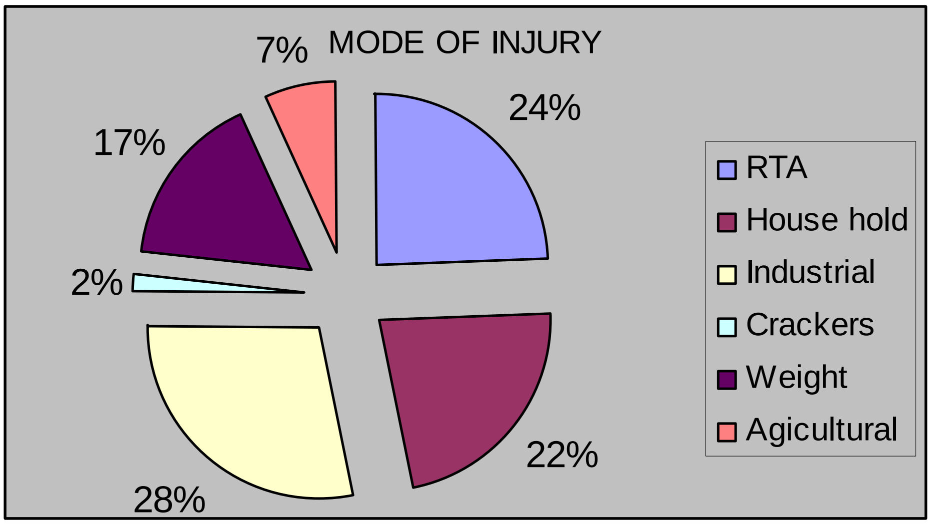
82% of cases had unstable fractures which needed reduction and some method of maintaining it. Most of the stable fractures were treated conservatively.



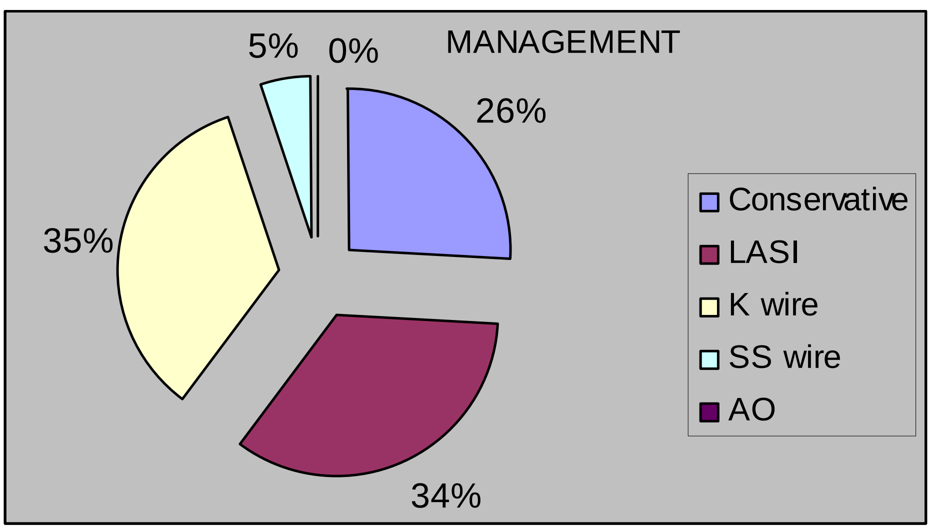
Unicondylar undisplaced fractures were most common followed by Unicondylar displaced. Bicondylar fractures were not seen in our series.



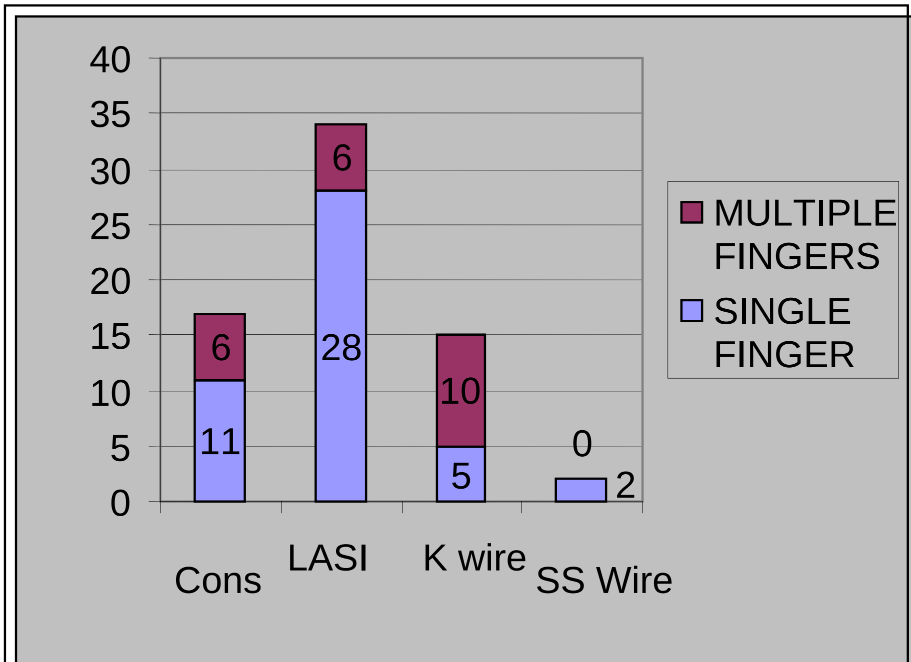
87 patients (48%) had displacement. Angulation had been the most frequent displacement. 29% of cases had combination of the three.



RTA, household and industrial injuries were most frequently seen. Industrial, cracker and RTA injuries were the mostly grievous types- compound & comminuted.

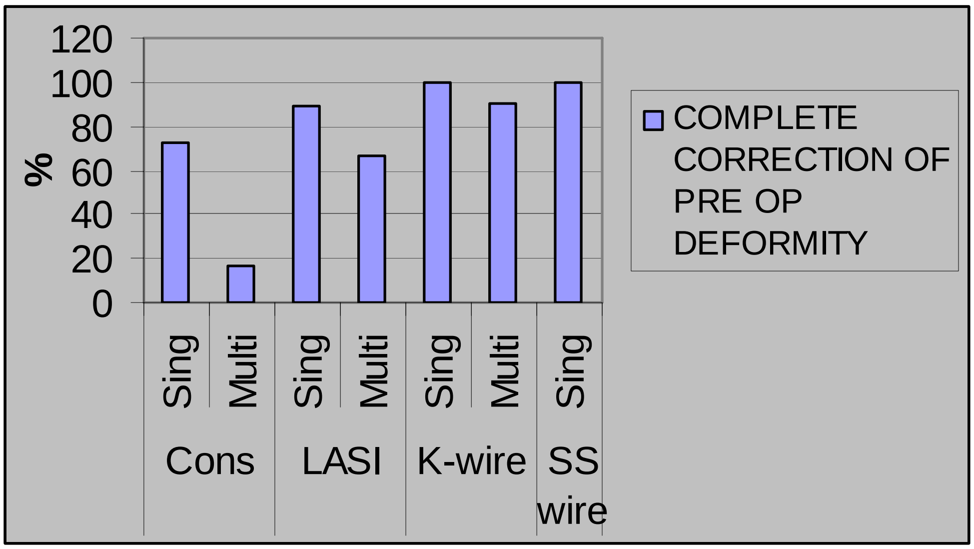


Most frequent type of management had been LASI & K-wire, the next commonest being conservative

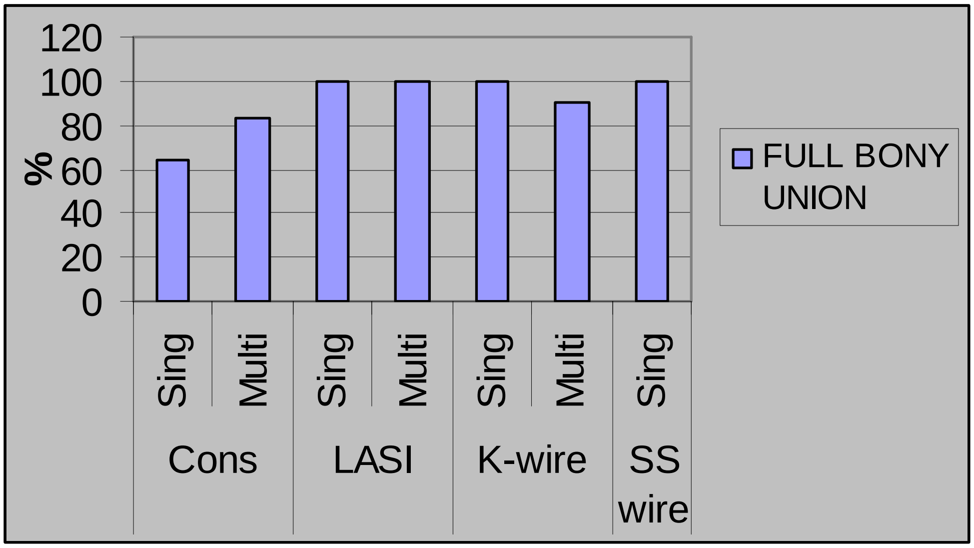


REVIEWED CASES

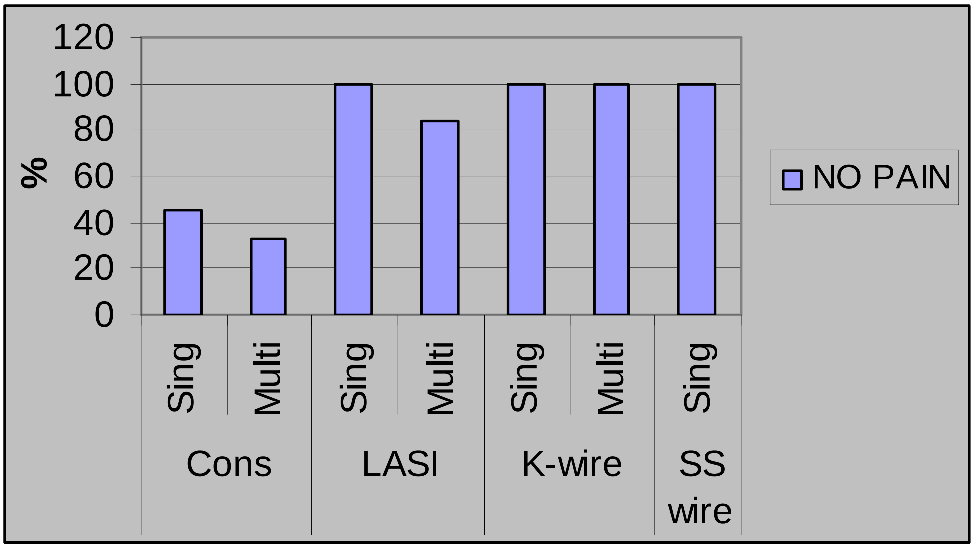
Of the 180 cases treated only 68 came for regular follow-up for up to 3 months. These patients were taken up for assessing the results of various treatment regimens. The breakup of single and multiple finger injuries are shown.



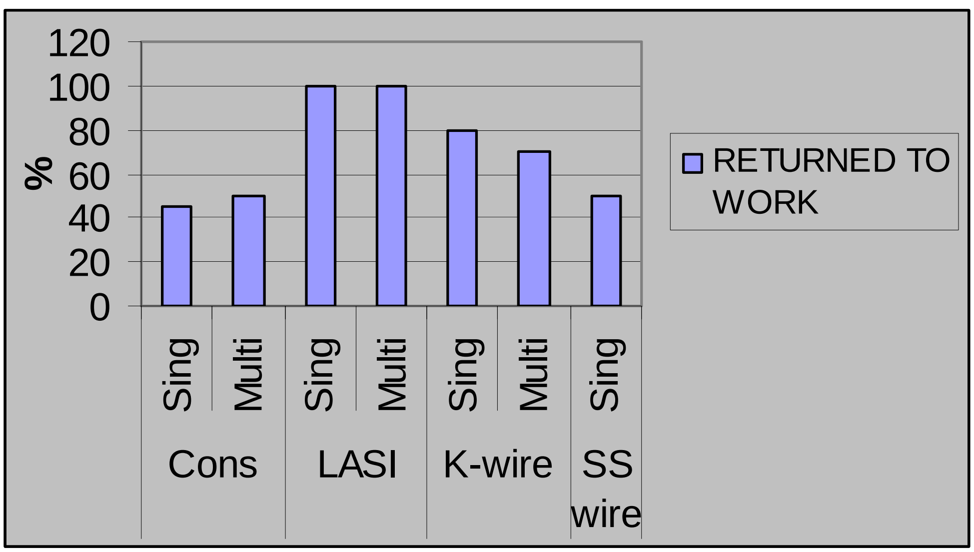
Deformity correction is best with K-wire & SS wire where>80%of patients had complete correction of deformity. LASI gives good results in single finger injuries



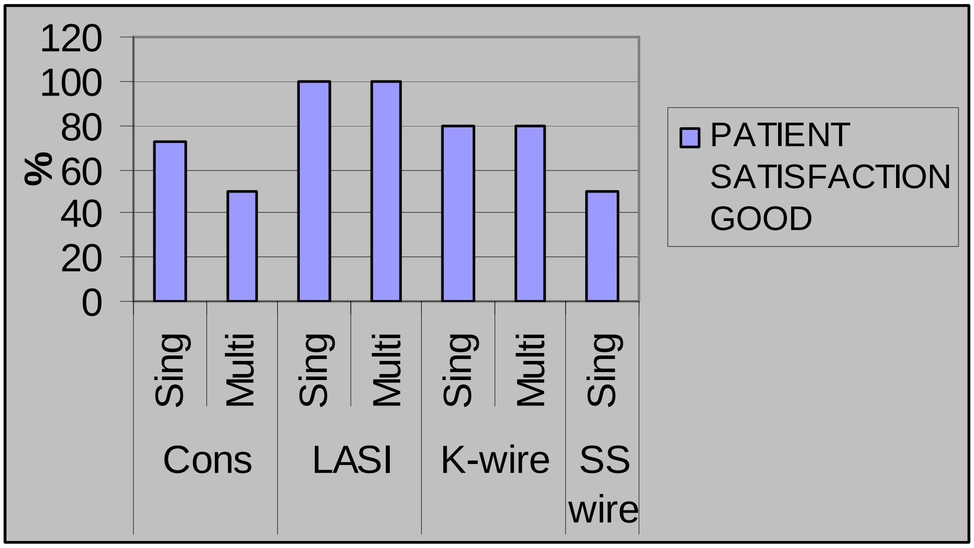
Full bony union was achieved in >80% of cases in LASI, K-wire, & SS wire fixation. Results were poorer in those treated conservatively. Results were poor in multiple fractures



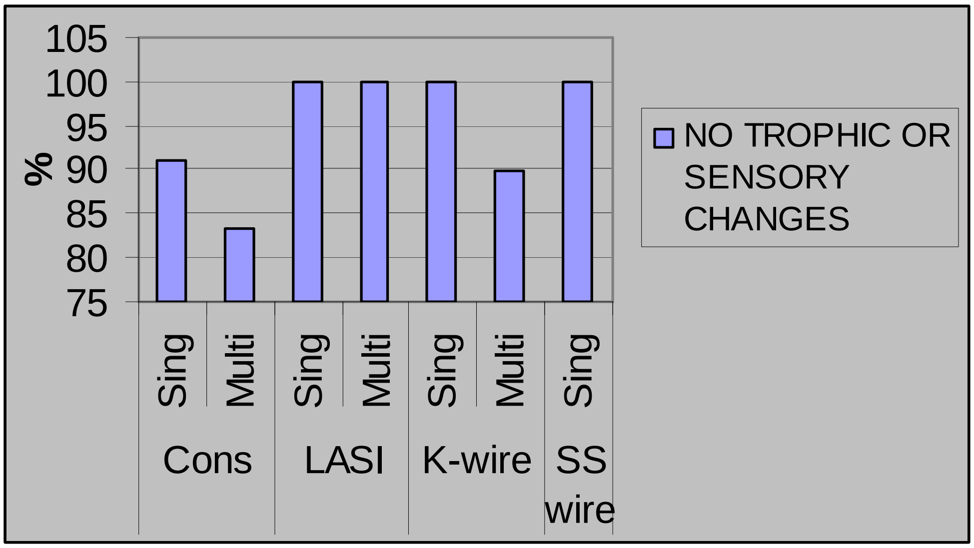
Nearly all the patients treated with LASI,K-wire & SS wire were free of pain 3 weeks post op. Results were poorer in those conservatively managed



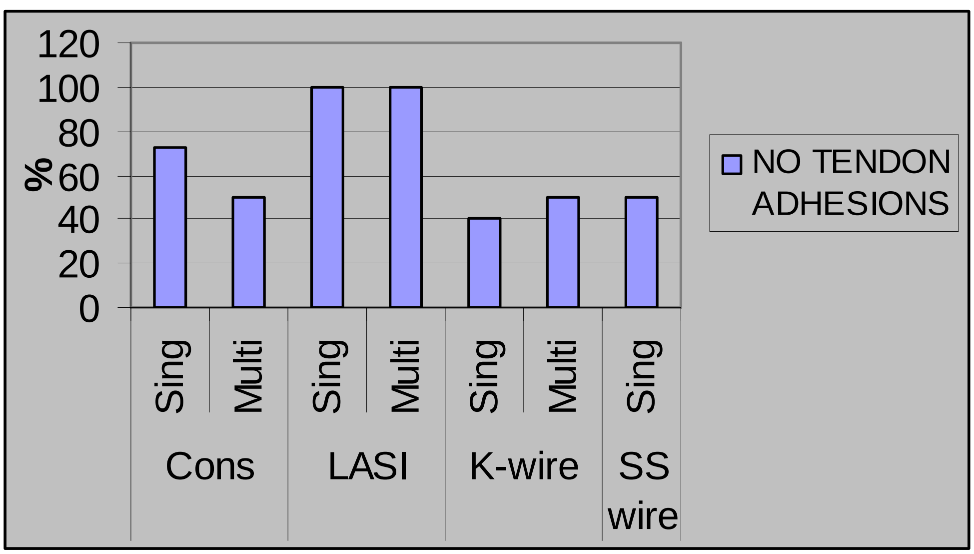
All of the patients treated with LASI returned to their previous work by 3rd month post op. Comparatively less of them returned within 3m when managed by other methods.



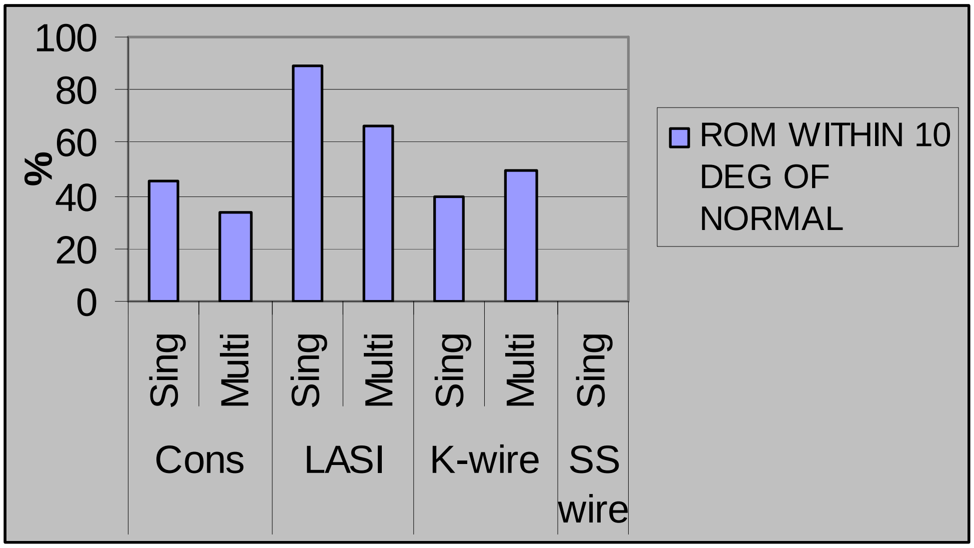
Patient satisfaction is the best when managed by LASI, as compared with other methods of management.



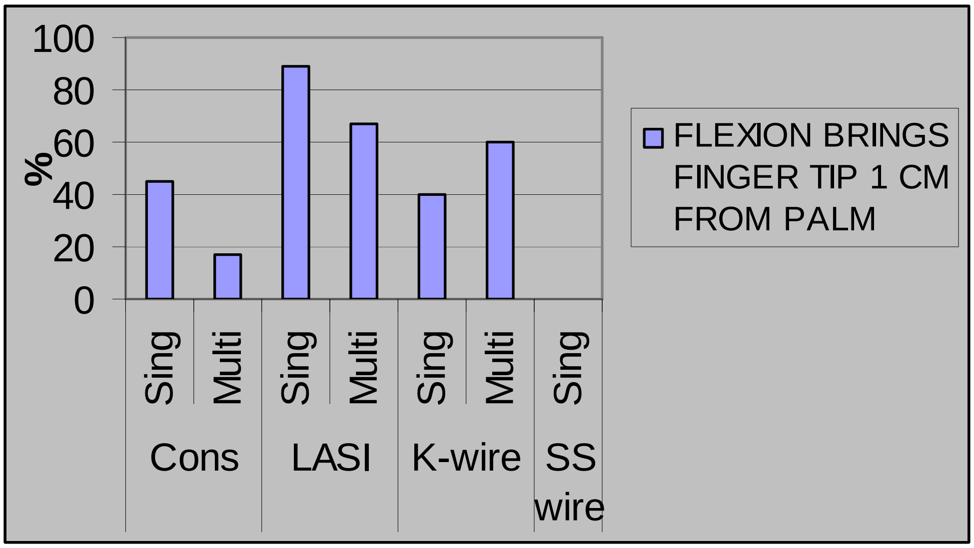
These were minimal in patients treated with LASI, K-wire & SS wire. It related to severity of injury to surrounding soft tissue sleeve



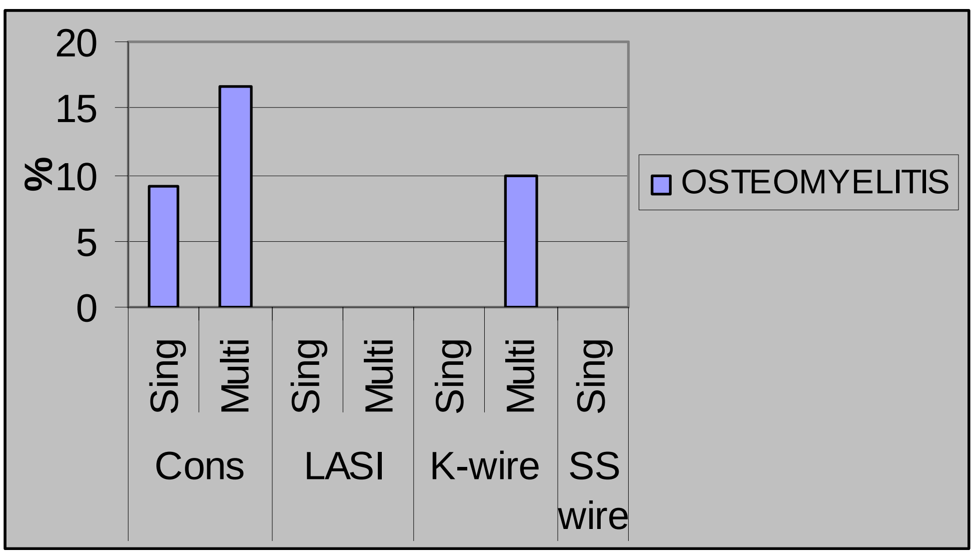
Injury to surrounding soft tissue sleeve is minimal in LASI & conservative treatment, so is no of tendon adhesions



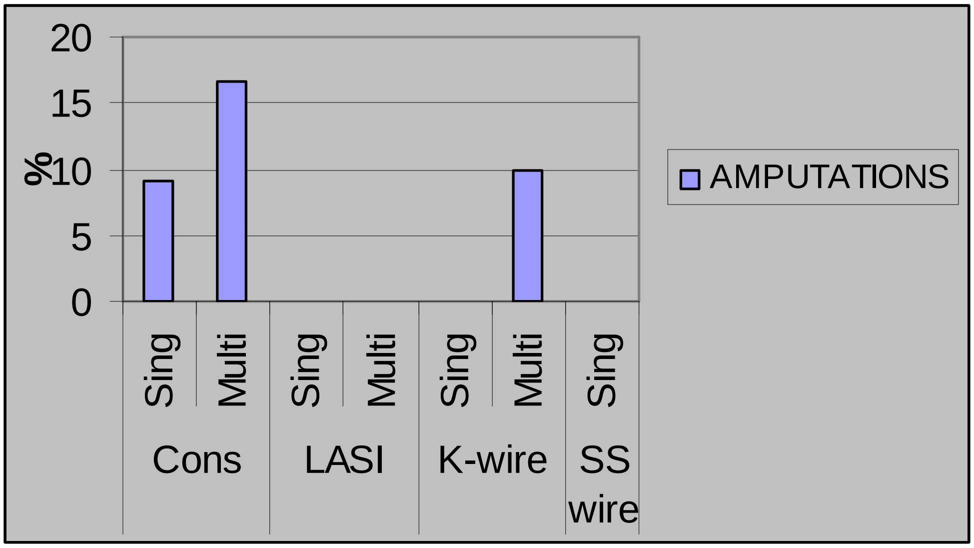
ROM at MP and IP joints is best in LASI as compared with other methods of management.



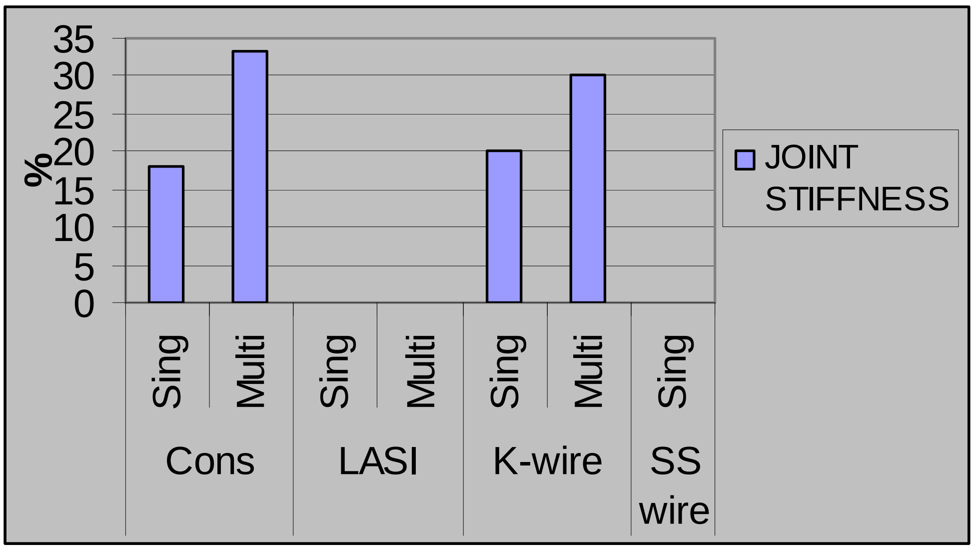
Single finger injuries treated with LASI have the best functional range of movements in over 80% of patients.



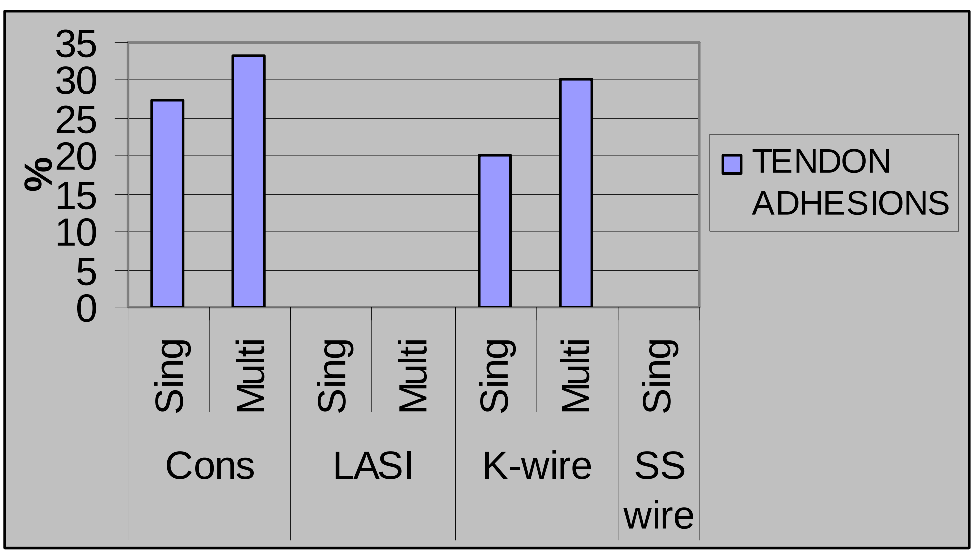
Need for sequestrectomy is much less in treatment with LASI, owing to the lesser severity of injury to soft tissue sleeve in patients selected.



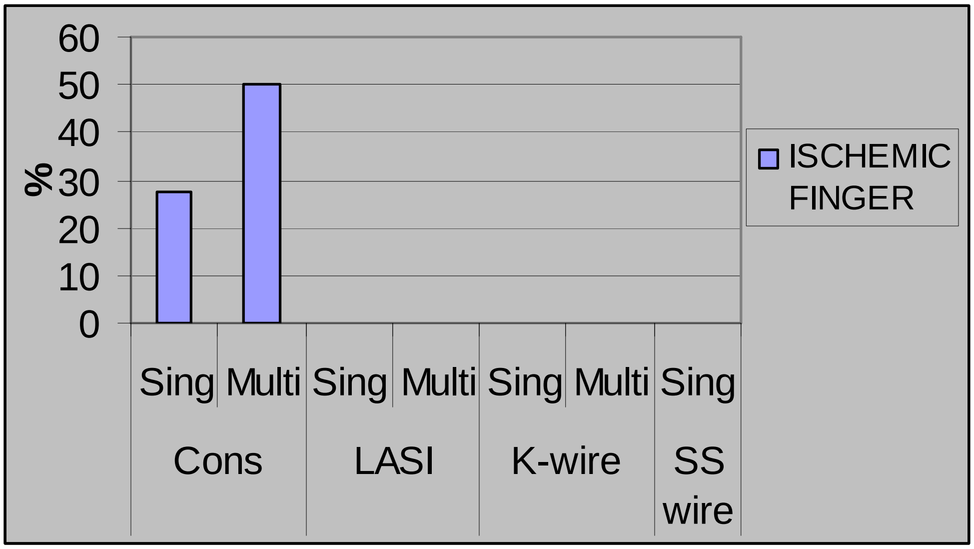
Doubtfully viable fingers subsequently needing amputations were maximum in conservatively treated patients and those with multiple finger injuries treated with open reduction



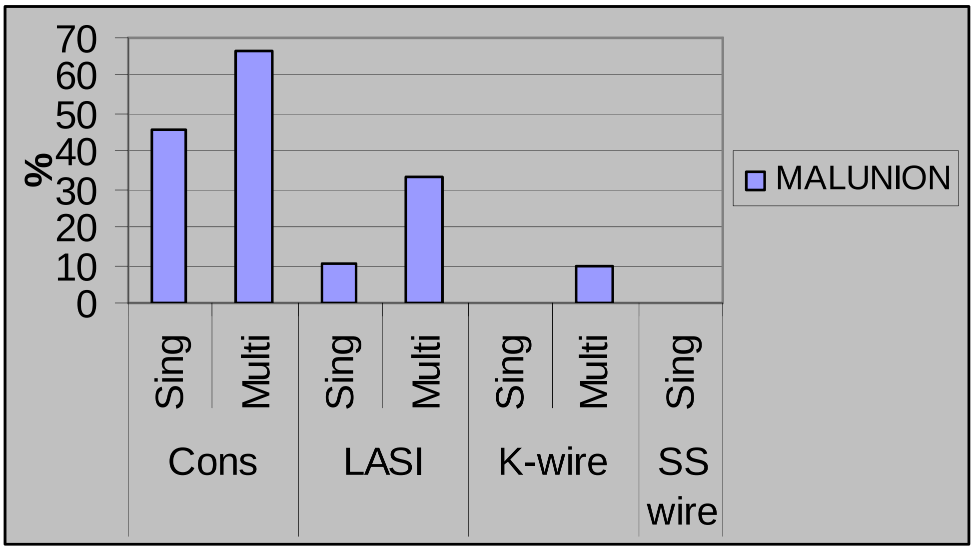
Joint stiffness leading needing Capsulotomy were not required in patients treated with LASI compared to those with other methods.



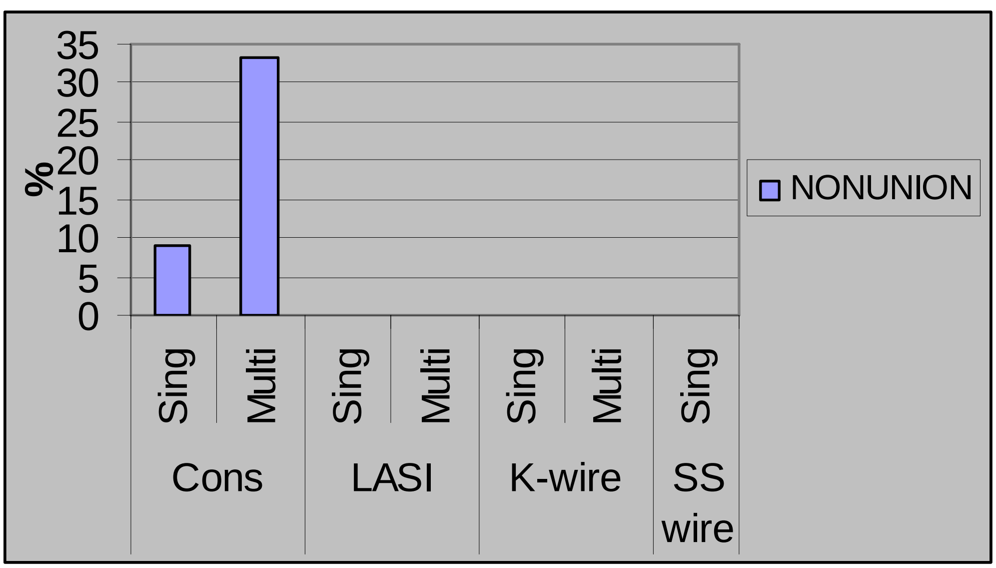
None of the patients treated with LASI needed Tenolysis. Those treated with other methods either had severe injuries or sustained operative trauma to tendons which caused adhesions.



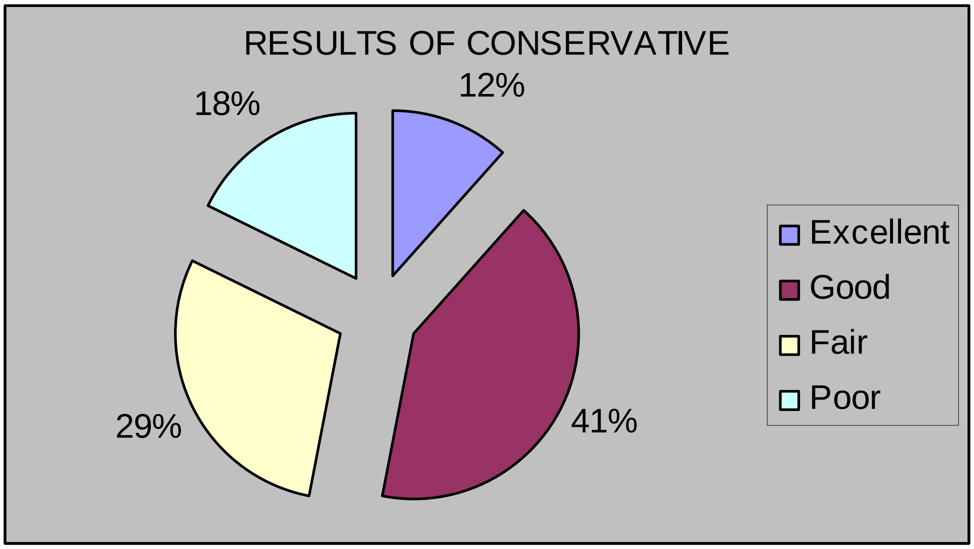
Surviving but ischemic finger was frequently seen in patients treated conservatively due to the fact that one of the indications for conservative treatment is doubtful viability.



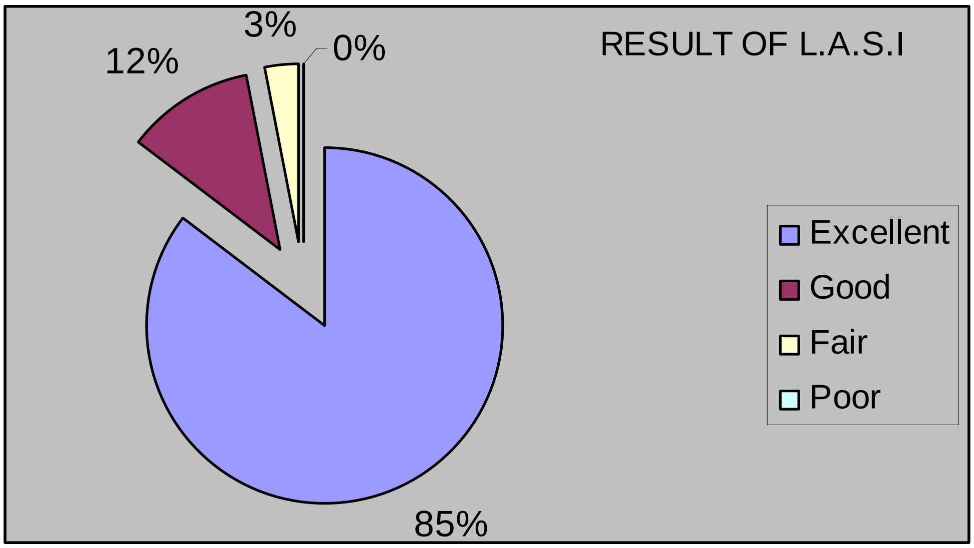
Malunions were frequent in patients treated conservatively. They were least in patients treated with K-wire or SS wire



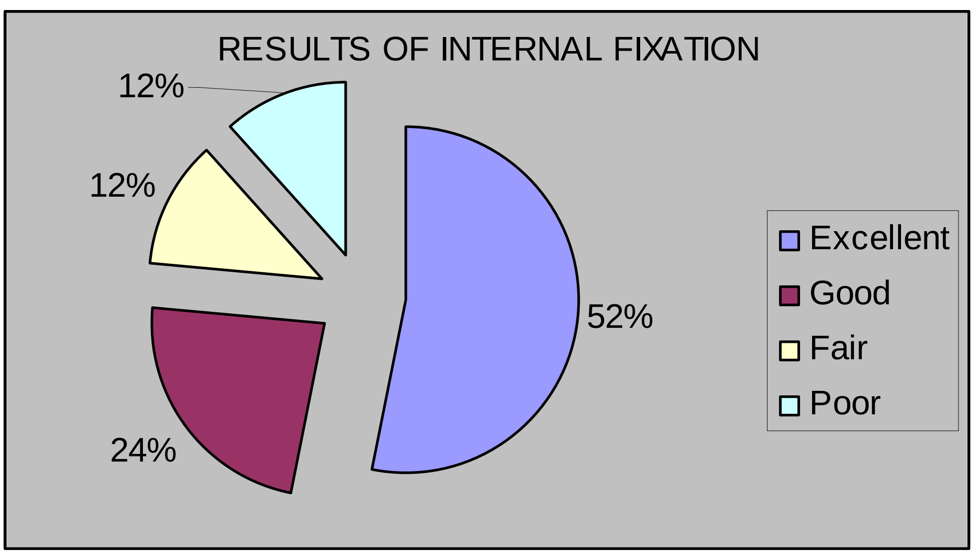
Nonunions were only seen in patients treated conservatively more so in multiple finger injuries.



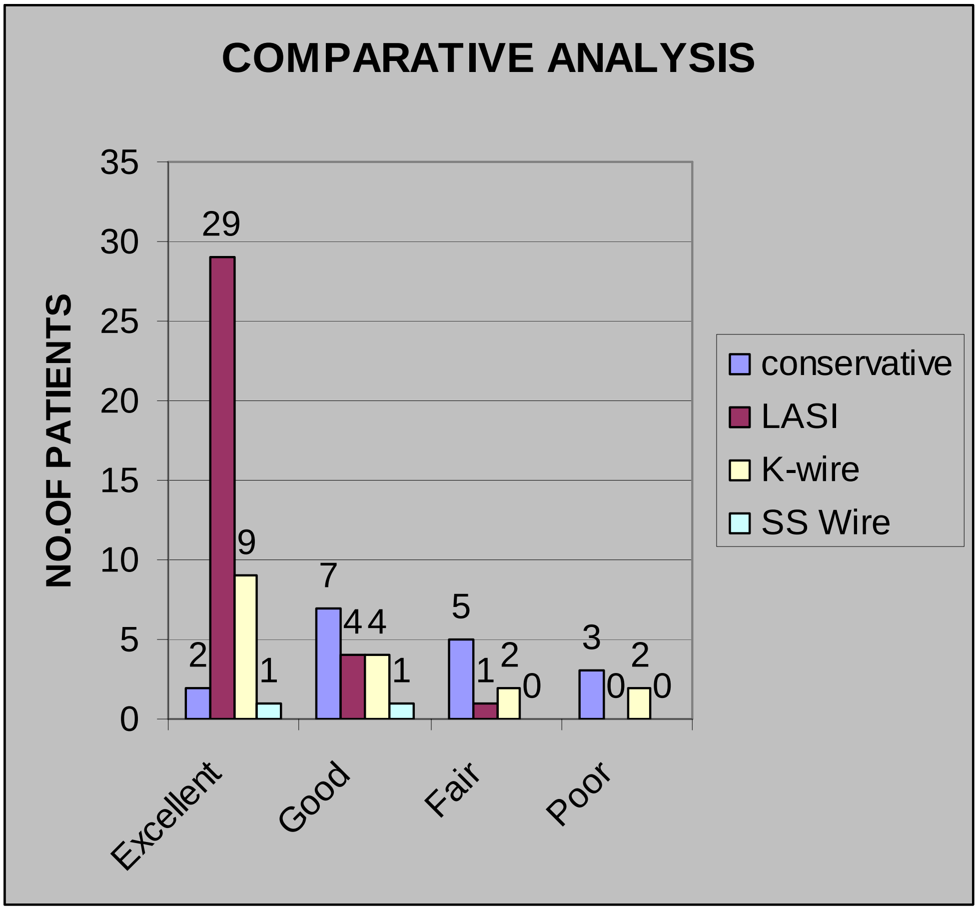
Conservative management gives good and fair results in 70% of patients. 18% of patients had poor results.



LASI gives excellent results in 85% of patients. Poor results are rare, probably due to patients selected and less tissue manipulation involved.



Internal fixation - K-wire and SS wire gives excellent results in 52% of patients, which is much less compared to LASI. 2/3rd of patients had excellent or good results.



This comparative analysis shows maximum no of patients had excellent results from treatment with LASI, when compared to those managed by other methods.

CONCLUSION

CONSERVATIVE TREATMENT

1. It is ideal for management of patients with multiple injuries, comminuted fractures and those with vascular problems
2. The over all results of conservative management are poor in terms of final outcome results. This could be due to indications for this line of management which chooses those with severe injuries involving the soft tissue envelop.

LONG ALUMINIUM SPLINT IMMOBILIZATION

1. It is most simple least invasive procedure

2. It does not require sophisticated bone instruments or manipulation.

3. It is cheap in terms of raw materials which include: aluminum splint which can be easily procured cheaply, POP, Prolene suture, & bandage materials.

4. It is a technically easier procedure compared with other methods of internal fixation.

5. It does not take more than 30 minutes to complete the procedure.

6. It is ideally suited for simple fractures of proximal phalanx involving one or more fingers or compound fractures involving single finger.

7. Post application manipulation of fracture if reduction not ideal is very easy. It is not possible in any other method of management.

8. Post operative results are excellent in more than 80% of patients, poor results are rarely seen.

9. Number of complications needing secondary procedures is much less when compared with other methods of management.

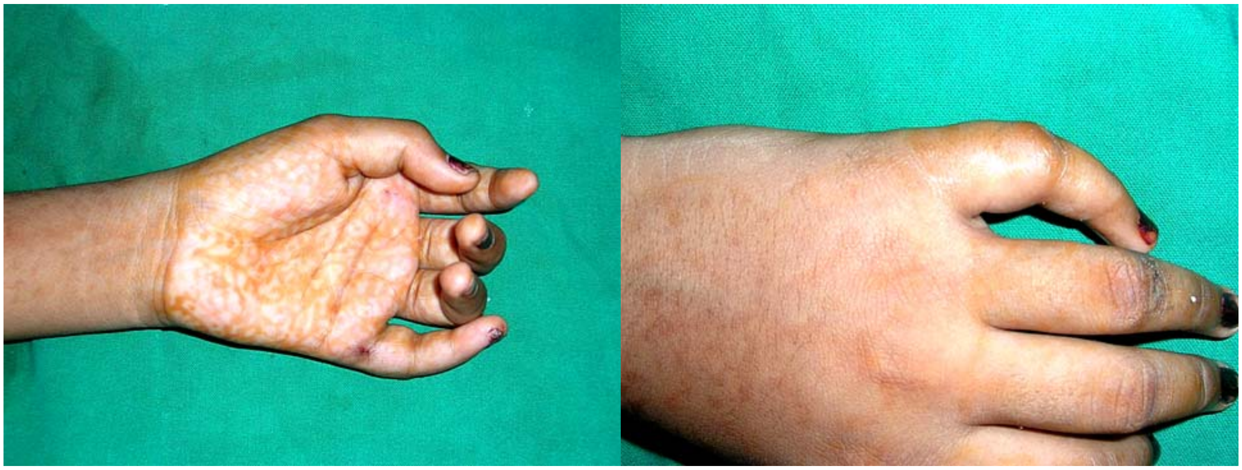
10. This procedure has a fast learning curve. Results obtained in hands of even a beginner are good.

11. This procedure allows a larger margin of error which can be easily rectified.

12. Drawbacks however are patient compliance is less due to splint projecting in front of finger. It is also prone to injuries which can jeopardize the fracture immobilization. Nail injuries, prolene suture cutting away are rarely seen. None were encountered in this series

K-WIRE FIXATION & S.S.WIRE FIXATION

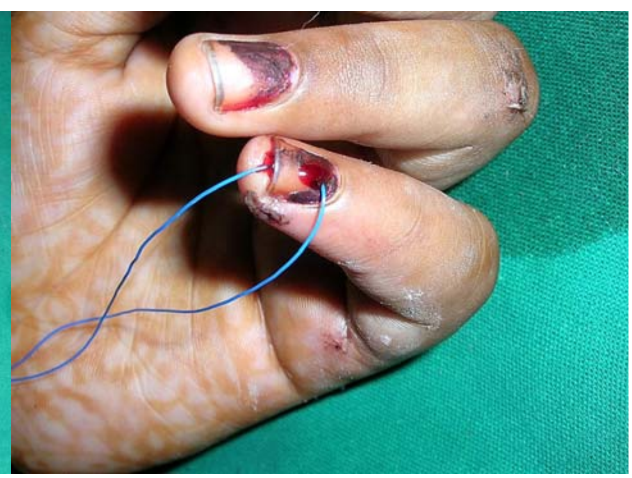
1. This procedure is ideal for compound fractures involving multiple fingers or hand
2. It is technically difficult
3. Margin of error is less
4. It needs specialized bone equipments – drills and K-wires
5. Injuries to adjacent soft tissue envelop to skin, tendons vessels and nerve is significant. this compromises in the final outcome
6. Injuries to joint articular surface while introduction is common. this could be one of the reasons for post operative stiffness.
7. Functional outcome of management by this method shows good and fair results in 75% of the patients.



A CASE OF FRACTURE OF PROXIMAL PHALANX OF LITTLE FINGER

X-RAY SHOWING FRACTURE

SPLINT PREPARATION



NAIL STITCH WITH 2-0 PROLENE

SPLINT EMBEDDED IN POP

NAIL STITCH USED FOR REDUCTION AND IMMOBILIZATION

POST REDUCTION X-RAY

FRACTURE BASE OF PROXIMAL PHALANX OF MID, RING, LITTLE

ALL THREE FINGERS IMMOBILIZED IN LONG ALUMINIUM SPLINT

POST OPERATIVE X-RAY GOOD REDUCTION

FRACTURE OF SHAFT OF RING AND LITTLE FINGER SHAFT

BOTH FINGERS IMMOBILIZED IN ALUMINIUM SPLINT

DISPLACED AND ROTATED FRACTURE OF SHAFT OF INDEX AND UNDISPLACED FRACTURE OF BASE OF MID PPX

FRACTURE FIXED WITH 2 CRISS CROSS K WIRES & MOULDING OF MID


OBLIQUE FRACTURE OF SHAFT OF INDEX PROXIMAL PHALANX FIXED WITH OBLIQUE AND TRANSVERSE K-WIRE


MULTIPLE FRACTURES OF HAND FIXED BY OPEN REDUCTION INTERNAL FIXATION USING COMBINATION OF K-WIRES AND SS WIRES

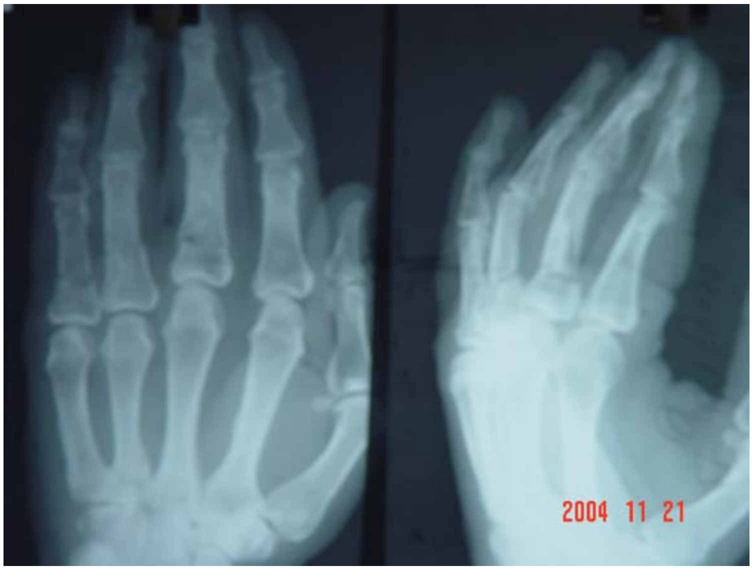

FRACTURE OF NECK OF PROXIMAL PHALANX OF MID- UNSTABLE


FIXED WITH A COMBINATION OF K-WIRE & SS WIRE

FRACTURE OF NECK OF PROXIMAL PHALANX OF RING FIXED USING SS -WIRE

COMPOUND COMMINUTED FRACTURE OF PROXIMAL PHALANX OF RING WITH BONE LOSS

FRACTURE FIXED USING EXTERNAL FIXATOR



Post operative x-ray of pt treated with LASI shows good reduction and good union

Post operative x-ray showing good reduction of fracture proximal phalanx index and mid fingers treated with LASI at 3 weeks

Spiral fracture treated with LASI

DISCUSSION

CLINICAL EVALUATION

As in any trauma it is essential to rule out other life threatening injuries and treat the body as a whole before attending to hand injuries that are rarely life threatening.

History

It is essential to note.

Type of injury: crush / sharp / blunt / blast / avulsion

Nature of force, duration, direction

Nature of primary treatment

Interval elapsed from time of injury to arrival to hospital

Additional considerations to be noted are: age, sex, occupation, socioeconomic status, systemic illness, tobacco smoking.

CLINICAL EXAMINATION

Symptoms: Pain swelling,

Restriction of motion,

Alteration of sensation,

Deformity

Signs: Tenderness,

Deformity (pseudo clawing due to volar angulation of ppx, compensatory hyperextension at MP joint and flexion at PIP joint)

Abnormal mobility,

Shortening,

Crepitus,

Rotation (digital overlap or scissoring)

Viability of finger

Sensory examination

Active and Passive movement at proximal and distal joints

Clinical examination should evaluate injuries to skin, neurovascular bundles, and flexor & extensor mechanisms (**Soft tissue envelop**), in addition to injuries to bones, joints and ligaments (**skeletal**)

Radiological examination

Appropriate x-rays of hand Antero- Posterior, True lateral, Oblique views should be obtained and following factors must be looked for

Location of fracture: Head, Neck, Shaft, and Base

Intraarticular or Extraarticular

Fracture geometry: Transverse, Spiral, Oblique, or Comminuted

Deformity: Angular, Rotational, and Shortening

MANAGEMENT OF PHALANGEAL FRACTURES

INDICATIONS FOR CONSERVATIVE TREATMENT

All simple Fractures that are stable without unacceptable displacement, or are stable after reduction are conservatively treated. The management being, protective splintage for 1 week, with early mobilization.

Methods used for immobilization are –

1. **Buddy splint -** Taping to adjacent normal finger
2. **POP immobilization** where adjacent fingers splint the fractured finger.
3. **Long Aluminium Splint Immobilization**

INDICATIONS FOR PHALANGEAL FRACTURE FIXATION

1. Irreducible fractures

2. Malrotation (spiral and short oblique)

3. Intraarticular fractures

4. Subcapital fractures

5. Open fractures

6. Segmental bone loss

7. Polytrauma with hand fractures

8. Multiple hand or wrist fractures

9. Fracture with soft-tissue injury (vessel, tendon, nerve, skin)

10. Reconstruction (i.e., osteotomy)

METHODS USED FOR FIXATION

There are multiple methods available for fracture fixation. Each has it own indications advantages and disadvantages. The following table enumerates the methods and its indication advantages and disadvantages.

FACTORS INFLUENCING OUTCOME FOLLOWING PHALANGEAL FRACTURES

PATIENT FACTORS

1. Age
2. Associated Diseases and Arthritis
3. Socioeconomic status
4. Motivation & Compliance

FRACTURE FACTORS

1. Location intraarticular vs. extraarticular
2. Geometry
    a. Simple , Comminuted, Impacted, Bone loss
    b. Transverse, Oblique, Spiral, Avulsion
    c. Deformity, Angulation, Shortening, Rotation
3. Stability
4. Injury to soft tissue sleeve
5. Associated injuries: Tendon, Ligament Joint, Vessel, Nerve, other Digits

MANAGEMENT FACTORS

1. Diagnosis and Recognition
2. Reduction and Maintenance
3. Length of immobilization
4. Post operative physiotherapy
5. Recognition and Management of complication

FRACTURES OF PROXIMAL PHALANX

It is convenient to divide Fractures into Articular and Nonarticular injuries. **Articular Fractures** include **-** Condylar Fractures, Comminuted intraarticular Fractures, Dorsal, Volar, or Lateral Base Fractures: Fracture –Dislocations; and Shaft Fractures extending into the joint. **Extraarticular Fractures** include Fractures of the neck, shaft, or base.

ARTICULAR FRACTURES OF THE PHALANGES

CONDYLAR FRACTURES

Condylar Fractures were classified by ***London*** in 1971.

1. Type I consists of stable Fractures without displacement,
2. Type II includes Unicondylar, unstable Fractures, and
3. Type III Fractures are Bicondylar or comminuted.

They are common athletic injuries; Unicondylar Fractures of the proximal phalanx tend to be missed because the athlete can often bend the finger quite well. Oblique x-rays are mandatory to properly visualize the fracture and adequately assess displacement (***Stark)***. If the initially undisplaced fracture is misdiagnosed as a sprain and the patient continues to use the hand, subsequent displacement with angulation of the finger and joint incongruity is likely.

Weiss and Hastings noted following interesting points

1. Even initially Nondisplaced Fractures are inherently unstable five of seven Fractures initially treated with a splint became displaced. Therefore, nonoperative management warrants extremely close careful x-ray follow up is mandatory to avoid a Malunion with articular incongruity.

2. Fixation with a single Kirschner pin is inadequate; the preferred fixation techniques include multiple Kirschner pins, mini screw (s) or a combination of two. Of these, multiple K-Wires provided the best final range of motion at the PIP joint.
3. Regardless of the fracture pattern, full range of motion at the PIP joint was unlikely and was secondary to a flexion contracture and/or extensor lag.

Displaced Unicondylar fracture requires open reduction and internal fixation. The various methods followed are:

1. Combination of interosseous compression wiring and a single Kirschner pin ***(Rayhack and Bottke)***
2. **Dynamic Flexible External Fixator** (***Fammy Harvey)***

Postoperatively, it is not infrequent to see a 20 to 30 degree PIP flexion contracture or an extensor lag. Some correction of this problem can be obtained by Dynamic Extension Splinting.

Bicondylar Fractures and comminuted intraarticular Fractures can be very difficult to fix. The various methods used are:

1. Minicondylar plate ***(Buchler and Fischer)***.
2. Dynamic traction ***(Schenck)***.
3. Primary joint Arthrodesis ***(Steele).***
4. **Spring-Loaded External Fixation Device** ***(Fahmy)***.

APPROACH

The fracture is exposed through either a dorsal Radial or dorsal Ulnar curved longitudinal incision. The joint is entered between the central tendon and lateral band. The central tendon should not be detached from its insertion into the dorsal of the middle phalanx. Fracture Hematoma is removed, with care taken to not detach the Condyle from its attachment to the collateral ligament. Under direct visualization, the fracture is anatomically reduced with a bone Tenaculum and reduction confirmed fluoroscopically. The condylar fragment is fixed with two parallel K-Wires or (0.028 or 0.035 inch) drilled through the fragment into the intact bone.

Interfragmentary screw fixation with two 1.5-mm screws can be used if the fracture fragment is 2 ½ to 3 times the external diameter of the screw. The dorsal apparatus is approximated with either running or inverted nonabsorbable suture. Postoperatively, early active motion is initiated and the IP joint is splinted in extension to avoid extensor lag. Kirschner wires are removed at 3 to 4 weeks. Screws do not require removal unless they are symptomatic.

Closed Reduction and Percutaneous Pin Fixation. Using mini-C-arm, a pin is placed into the condylar fragment and used as a joystick to manipulate the fragment into its anatomic position. The reduction is provisionally maintained with a bone Tenaculum, and the reduction is verified with the image intensifier. Fixation is then secured with two to three appropriately sized Kirschner pins. This technique has the advantage of minimizing soft-tissue dissection, but it can be tedious and does not allow direct visualization of the fracture to verify reduction.

Osteochondral slice fractures are fixed by drilling two 0.028-inch Kirschner pins retrogradely out of the side of the phalanx, reducing the fracture, and then drilling the pins to a subchondral position.

Bicondylar fractures of the proximal phalangeal head are nearly always displaced and often comminuted. Anatomic restoration of articular congruency usually cannot be accomplished by closed manipulation. Open reduction using the same approach as for Unicondylar fractures is advised. First, the two condyles are reduced and fixed to each other with either a screw or Kirschner pins. Next, the head fragment is secured to the shaft in a similar fashion. Supplemental cancellous bone graft may be added if there is significant Comminution.

Post operatively Early range of motion is encouraged; however, residual stiffness and/or extensor lag is not uncommon.

In **Significant Comminution,** open reduction may be frustrating and restoration of the articular surface may be impossible. In such circumstances, skeletal traction is applied through the middle phalanx for 3 ½ to 4 weeks. The traction is secured to a fore-arm based splint to immobilize the proximal phalanx but allow active fixation of PIP joint. Fracture consolidation can be anticipated, and some articular remodeling will occur. Restoration of full motion is unlikely. Primary Arthrodesis is unpredictable and may result in excessive shortening.

Extensive Comminution of the phalangeal head may preclude satisfactory open reduction. These fractures are frequently associated with significant damage to the soft-tissue sleeve and best treated non-operatively. Treatment can consist of manual molding to restore general alignment, immobilization for 10 to 14 days, and early protected motion or traction.

OTHER FRACTURES OF THE HEAD OF THE PHALANX.

Displaced collateral ligament avulsion fractures of the head of the proximal phalanx may be symptomatic if nonunion or fibrous union results. Open reduction or repair of these injuries should be done more often than currently practiced, especially if the injuries are associated with lateral instability. A Pseudoboutonniere deformity develops when the ligamentous and the resultant fracture healing cause's adhesions between the adjacent lateral band, oblique retinacular ligament, and volar plate.

DORSAL, VOLAR, OR LATERAL BASE FRACTURES AND PHYSEAL FRACTURES

Fractures of the lateral volar base of the proximal usually represent collateral ligament avulsion injuries. **Minimally displaced lateral corner fractures** that do not compromise joint stability or result in an incongruous articular surface can be treated by splinting for 10 to 14 days, followed by protected motion. **Significantly displaced lateral corner fractures** (displaced more than 2 mm) may compromise joint stability. The recommended treatment is open reduction and fixation with either Kirschner pins or tension wires.

Epiphyseal fractures of proximal phalanx are extraarticular (85 – 90%) can be treated by closed reduction and splinting. Salter – Harris type 3 fractures are more common in proximal phalanx because of insertion of collateral ligament exclusively in epiphysis (unlike in middle phalanx where it extends beyond). Displaced Salter – Harris type 3 or 4 Epiphyseal fractures require accurate open reduction through dorsal tendon splitting incision.

T-fractures of base of proximal phalanx require open reduction internal fixation through dorsal tendon splitting incision by minicondylar plate or k-wire.

SHAFT FRACTURES INVOLVING THE JOINT

Long spiral fracture of proximal phalanx may project into Retrocondylar space of IP joint and block flexion. Open reduction internal fixation is indicated. In late cases blocking bony projection can be removed to improve movement.

NON ARTICULAR FRACTURES OF PROXIMAL PHALANX

NECK FRACTURES (Subcapital)

These are uncommon in adults and can be managed by closed reduction and splinting or percutaneous crossed K-wire. These fractures are more common in children while violently withdrawing trapped finger from closing door. Serious nature of this fracture is seen only in true lateral x-ray where head fragment is displaced dorsally and rotated 90 deg so that articular surface faces dorsally.

Management of these fractures is by open reduction internal fixation for extended period of 6 weeks. If reduced after closed reduction, internal fixation was done by crossed K-wire from each side of distal fragment into the shaft percutaneously (***Segmuller and Schoenberger***). For fractures that cannot be reduced by closed reduction open reduction by dorsal approach between central tendon and lateral band, pushing

Palmar plate out of joint and maintaining reduction with two crossed K-wires for 6 weeks (***Campbell***).

Delayed open reduction internal fixation can be carried out as late as 4 weeks.

SHAFT FRACTURES

Phalangeal fractures can be transverse, oblique or spiral, and comminuted. Spiral and oblique fractures are more common in the proximal phalanx, where as transverse fractures tend to be more common in the middle phalanx. Proximal phalangeal fractures angulate volarly, the proximal fragment being flexed by the strong interosseous muscles.

HEALING TIME. There lack of correlation between x-ray and clinical signs of union of phalangeal fractures. The average time for complete bony healing was approximately 5 months ***(Smith Rider)***. The average time for clinical union was 5 to 7 weeks for the middle portion of the proximal phalanx (hard cortical portion) (Moberg***)***.

CLOSED REDUCTION WITH A CAST OR SPLINT

Manual reduction by ***Jahss manouver*** reduced a proximal phalanx fracture by flexing the MP and PIP joints in full flexion. The taught dorsal apparatus overlying proximal phalanx acted as tension band reducing the fracture and similar positioning of adjacent fingers controlled rotation and angulation (***Burkhalter***)

To avoid contracture of collateral ligaments that occurs with MP extension, MP joints are maintained in 90 deg flexion. PIP joints are held in nearly full extension to prevent collateral ligament and volar plate contracture that occurs with flexion (***James***

position). For unstable fractures closed reduction and splint immobilization for 3 weeks, for stable fracture buddy taping with immediate mobilization ***(James principle)***

Burkhalter management regimen for proximal phalanx fractures -- closed reduction and immobilization in short arm cast with wrist in 30- 40 deg extension. Dorsal plaster extension block is added to hold MP in 90 deg flexion and IP joint fully extended. Program of immediate active flexion is initiated

TRACTION

Traction can be applied through skin, nail, and skeleton. It has the advantage of being minimally invasive and simple, but drawbacks are that they are difficult to maintain and cumbersome. The methods used are:

1. Skin traction maintained for 2 ½ **-** 3 weeks followed by active range of motion with buddy taping (***Rooks).***

2. Skin or nail traction (nail stitch or through hook glued to nail (***Weeks and Gray***) is applied to finger in extension and attached to the end of splint which was then flexed.

3. Skeletal traction ***(Quigley and Urist***) was applied through fish hook inserted through hole drilled into base of middle phalanx in area of triangular ligament or ***(Lipscomb***) wire loop through shaft of 22g needle inserted through the tuft of terminal phalanx. Traction is only applied to maintain the reduced position after manually reducing the fracture (***Moberg***).

Drawbacks of this method are

a. Complications related to method of application

b. Joint stiffness

c. Difficulty in controlling fracture alignment

d. Counter pressure problems

EXTERNAL FIXATION

External fixation is indicated for open fractures, especially those with concomitant soft-tissue injury such as gunshot wounds, highly comminuted diaphysial fractures, severely comminuted articular fractures, and fractures with significant loss of bone stock. Advantages include ease of insertion, minimal dissection and devascularization of soft tissue and bone, and preservation of bony length, and it provides access for additional soft-tissue care.

Studies done by ***Ashmead et al, Bilos and Eskestrand, Smith et al,*** have shown that results are excellent. Metacarpo phalangeal motion was well preserved but loss of IP motion. They ascribed the ***IP joint stiffness*** to a variety of factors, including the magnitude of the soft-tissue injury, pins impaling the dorsal apparatus, and the intraarticular nature of several of the injuries. There were no iatrogenic tendon or Neuro-Vascular injuries, and the device was well tolerated psychologically. The various modifications described are:

1. Transverse Kirschner wires proximal and distal to the fracture that were bonded to external longitudinal Kirschner wires on each side with acrylic cement (***Scott et al).*** This was followed by Initiation of active motion at 1 week (***Shehadi).***

2. Technique for preservation of digital length following bone loss by. inserting a temporary block of silicone, and after soft-tissue healing, the silicone was successfully replaced by a bone graft (***Stern)***.

External fixation is particularly useful in comminuted fractures that require concomitant management of soft-tissue injury. This device could be replaced with pins, plates, or screws at the time of delayed primary bone grafting and definitive wound coverage (***Freeland)***.

PERCUTANEOUS PINNING

Percutaneous Kirschner wires fixation has the advantage of stabilizing the fracture and slowing early motion while minimizing injury to the soft-tissue sleeve. This technique is particularly useful in shaft fractures that are transverse, spiral, or oblique in orientation. Pin insertion should be done in the operating room, preferably with the aid of an image intensifier. It is often difficult to obtain complete reduction and the Kirschner wires passing through the soft-tissue envelope may limit or prevent early mobilization.

A variety of pin configurations have been described for percutaneous placement to stabilize transverse fractures

1. Intramedullary Kirschner wires fixation, introduced through the flexed IP joint distal to the fracture to maintain closed reduction of (middle and) proximal phalangeal fractures (despite the fact that the protruded through the joint for 4 to 7 weeks, no definite infections were seen) ***(Vom Saal*** & ***Clifford)***.

2. Intramedullary Kirschner wires through the flexed MP joint the fractures were immobilized for approximately 3 weeks ***(Kilgore and Graham & Belsky et al).***

3. For transverse fracture of the proximal phalangeal base. The flexed proximal fragment is immobilized by the pin while the distal fragment is reduced, the pin is then drilled across the fracture ***(Helm and Pfeiffer)***.

4. Single oblique Kirschner wires introduced through the head of the proximal phalanx with the PIP joint flexed 90 degrees. The pin is directed towards the more palmer position of the head to one side of the midline and aimed to come out the opposite corner of the base of the phalanx dorsally. The wire is then withdrawn proximally until the PIP joint is freely movable ***(Flatt)***.

5. Closed intramedullary Kirschner wires fixation introduced through the base of the proximal phalanx just distal to the MP joint ***(Joshi)***.

6. Glasgow and Lloyd modified standard AO reduction forceps by adding a barrel that would accept a 0.045-inch Kirschner wires. Adequate stability of the fragments is maintained while accurate insertion of the Kirschner wires is achieved.

7. **Percutaneous screw fixation** of a spiral/oblique fracture of the proximal phalanx. After a limited midaxial incision, two lag screws are inserted under fluoroscopic guidance. Although the efficacy of the technique is unproven, it has the advantage of providing more stable fixation than Kirschner wires but does not require the extensive dissection necessary for the open insertion of the lag screws, (***Freeland and Roberts***1991).

OPEN REDUCTION AND INTERNAL FIXATION.

If an unstable proximal phalangeal fracture cannot be reduced or if percutaneous pinning is not possible, open-reduction internal fixation becomes an option.

SURGICAL APPROACHES. The various approaches described are:

***1. Pratt* -** Obliquely angled dorsal dermal incision. The fracture was exposed by splitting the extensor mechanism longitudinally and closing it with a running pull-out wire suture. It has the potential disadvantage of causing scarring of the dorsal apparatus to the skin and bone.

***2. Posner* -** Mid-lateral incision and excised one of the lateral bands to expose the fracture. He opened the finger on the side of which the distal fragment had shifted. It is occasionally necessary to excise a portion of the extensor mechanism to expose the fracture.

***3*. *Heim and Pfeiffer* -**long dorsal lateral incision with curved ends to expose the proximal phalanx. The proximal portion of the phalanx was then exposed through a longitudinal split in the extensor tendon, and the distal part of the phalanx was exposed by elevation of the lateral extensor tendon.

***4. Field et al* -** midaxial approach to the proximal phalanx. They argued that scarring of the dorsal apparatus is less likely and PIP extensor lag is minimized.

***Barton* -** lateral incisions on both sides of the finger to expose and fix a proximal phalangeal fracture.

It is essential to preserve the dorsal veins and paratenon to avoid postoperative adhesions (***Jupiter and Silver)***.

The various means of fixation are:

K WIRE FIXATION

Smooth Kirschner wires have been by far the most popular technique of maintaining fracture reduction. A pin can usually be inserted with minimal soft-tissue stripping, thereby preserving the blood supply to bone and enhancing the potential for healing. In addition, Kirschner wires, when compared with a plate or screws, are less bulky, may be inserted so that the dorsal apparatus is not impaled, and allow for easy closure of the soft tissue.

Furthermore, pins are acceptable for nearly all fracture configurations. They have been used longitudinally or obliquely in the medullary canal for transverse or short oblique fractures. ***London*** even bundled Kirschner wires together to fill the entire medullary canal. Placement perpendicular to the fracture or bone is recommended for long oblique fractures, and crossed Kirschner wires are best for transverse fractures; however, distraction may be a problem if the bone ends are not firmly impacted during pin insertion. Pin replacement is easier in spiral fractures than transverse fractures because of the small diameter of the Diaphysis.

Considerable disagreement exists on whether the ends of the pins should be allowed to protrude through the skin or should be cut off beneath the skin. If the pins were left in for 3 weeks they could protrude, but if left longer, they should be cut off beneath the skin with 2 to 3- mm tail (***Kilboune)***.

Fractures stability is enhanced, when the Kirschner wires are supplemented with stainless steel (26-gauge) wire, a technique termed **composite wiring (*Green et al*).** The technique is particularly useful in spiral and should not be used in comminuted fractures. As the stainless steel wire which is looped under the pins, is clinched down, compression at the fracture site can be achieved.

SCREW FIXATION

Because a single longitudinal Kirschner wires does not provide rotational stability and crossed pins may distract the fracture, more rigid methods of fixation have been sought. Screw fixation enhances stability by using the **lag technique** to achieve interfragmentary compression.

They are particularly useful in oblique and spiral fractures when the fracture length is at least twice the bone diameter ***(Steel)***. A minimum of two screws are necessary and they should be inserted at least two screw diameters from the fracture edge and the screw should bisect the angle between a line perpendicular to the bone and one perpendicular to the fracture to obtain maximum compression and shear protection. In general, 2.0- and 1.5-mm screws are used in the proximal phalanx Smaller-diameter self-tapping screws of 1.0 to 0.75 mm may be useful on a limited basis.

Studies by ***Segmuller, Heim et al***, ***Ikuta Tsuge*** (micro-bolts and micro-screws), ***Crawford, &*** Ford ***et al*** have shown achieved satisfactory results in 90 percent of their cases at a mean follow-up of 24 months. They have recommended stabilization of long oblique and spiral fractures with a single lag screw. The screw fixation was superior because it allowed earlier mobilization (***Diwaker and Stothard)***

Recently, ***Freeland et al*** introduced the technique of percutaneous screw fixation for spiral phalangeal fractures. Following closed reduction (maintained with bone Tenacula), a Titanium self-tapping screw is inserted with fluoroscopic guidance through a small incision. The value of the technique is that it minimizes soft-tissue dissection. However, more experience will be necessary before it can be recommended.

INTRAMEDULLARY FIXATION

The various methods described for intramedullary fixation are:

1. Intramedullary Steinmann pin introduced through the ends of the fractured fragments(***Grundberg)***

2. Flexible intramedullary screw to provide axial compression (***Iselin and Thevenin)***

3. Multiple pre-bent flexible intramedullary pins After indirect fracture reduction, the pins were inserted under image intensification in an antegrade fashion through a hole in the dorsal cortex of the proximal phalanx (***Gonzalez et al)***

4. Expandable intramedullary device (***Nordyke et al)***

Immediate motion was permitted and they believed that the results were superior to those of other methods of internal fixation.

INTEROSSEOUS WIRING

Interosseous wiring is useful for transverse shaft fractures and also for articular fractures, comminuted fractures (***Gingrass et al*),** digital replantation (***Gordon and Monsanto*).** It requires minimal exposure, is less prominent than plates or screws, and theoretically minimizes the risk of adhesions to overlying tendons.

The various methods of fixation are:

1. Interosseous wiring dorsal to the flexion axis, supplemented with an oblique Kirschner wires (***Lister*).**

2. Two parallel interosseous wires running in a dorsal-volar direction. Drill holes are made with a straight needle on 4-0 pull-out wire (Ethicon) on the lateral aspect of the phalanx (to avoid the flexor and extensor mechanisms). The fracture is then reduced and the wires are twisted and bent into the fracture site (***Gingrass et al***).

3. Wire passage by using a 19-gauge needle with the tip slightly bent to drill the bone before passing the wire through when performing interosseous wiring (***Scheker***). Fixation can be supplemented with a Kirschner wires if there is a bone loss or instability. There is lack of interference with adjacent joint mobility and superior fixation. Restoration of active movement is good in this method.

PLATE FIXATION

Plate and screw stabilization of phalangeal fractures has the advantage of providing stable fixation, thereby permitting early range of motion. Plate application should be used sparingly and that simpler techniques should be used wherever feasible. Primary indication for application was in unstable comminuted diaphysial fractures (***Blair)***. This conservative approach seems justified inasmuch as plates may be difficult to apply and there is no margin for error. Extensive soft-tissue dissection may be necessary for exposure, plates are relatively high profile and may interfere with extensor tendon excursion or soft-tissue closure, and secondary removal may be necessary.

The various techniques used are:

1. **Lateral plate and screws** (***Dabezies and Schutte)***

2. **Low-profile Vitallium mini-plate** (***Thaller et al)***

3. **Maxillo-facial mini-plates and macro-plates** (0.8-mm screws) (***Puckett et al)*** screws are self-tapping, there is less periosteal stripping required for application, and the plates are low profile, which may result in less interference with extensor tendon excursion

4. **Laterally placed minicondylar plate** (1987, ***Buchler and Fischer)***

Lateral application of this plate resulted in less PIP flexion loss than did dorsally applied, hand straight plates. When applied appropriately total active motion of more than 220 degrees was seen in nearly all patients (***Dabezies and Schutte)***. When there was significant soft-tissue injury, good results were seen in only 5 percent of the fractures. Supplemental Kirschner wires fixation can be used if the construct is believed to be too fragile. Technical errors occurred in 18 percent of the cases, and secondary surgery was frequently necessary (***Buchler and Fischer)***

BIOMECHANICAL TESTING

Biomechanical testing on various implants may be difficult to compare because investigators use different testing conditions (four point bending verses three-point or cantilever bending), different bones, dissimilar implant constructs, and a variety of loads in different modes. Currently there is not enough information to determine how much stability is needed for a given fracture configuration to permit gentle active motion.

However experimental fractures of the proximal phalangeal shaft and testing by five methods of fixation by ***Fife and Mason, Gould et al*** & ***Massengill et al*** have shown

1. Straight Kirschner wires fixation proved to be the least rigid.

2. Crossed Kirschner wires fixation was more rigid, and interosseous wiring supplemented with an oblique Kirschner wires yielded the most rigidity and consistency

3. Kirschner wires fail as the result of loosening and sliding within the bone

4. Bone plate and screw fixation had maximum bending moments that approached those of intact bone

5. Volar or lateral plate and screw fixation was considerably stiffer and stronger than any configuration of the wire-loop or Kirschner wires

6. Tension band stabilization provides superior strength, stiffness, and approximation when compared with Kirschner wires fixation (***Gould et al***)

7. Single-looped tension based wires were superior in strength to figure-of-eight constructs (***Rayhack et al***)

8. Techniques that used interfragmentary lag screws provided more rigidity than did dorsal plating alone or crossed Kirschner wires (***Black et al***)

9. Intramedullary Kirschner wires and a cerclage interosseous wire, which theoretically provides compression as well as bending rigidity, were more stable than crossed Kirschner wires, as stable as cerclage wire and oblique pin but not as rigid as a dorsal plate.((***Hung et al***)

TECHINIQUE	*INDICATION*	*ADVANTAGES*	*DISADVANTAGES*
K- WIRE	Transverse, Oblique, Spiral	Available and versatile Easy to insert Minimal dissection Percutaneous insertion possible	Lacks rigidity May loosen May distract fracture Pin tract infection Required external support
INTER OSSEOUS WIRE	Transverse, Avulsion fractures, Supplemental fixation, Arthrodesis	Easily available Low profile Relatively simple	May cut out in osteopenic bone
COMPOSITE WIRING	Transverse Oblique Spiral	More rigid than k wire Low profile Simple and available	Migration pin/ wire Secondary removal Significant exposure
INTRA MEDULLARY DEVICE	Transverse Short Oblique	No special equipment Easy No pin protrusion Minimal dissection	Rotational instability Rod migration
INTER FRAGMENT ARY FIXATION	Long oblique Spiral	Low profile Rigid	Special equipment Little margin for error
PLATE AND SCREW FIXATION	Multiple fractures Bone loss Intra/peri- articular Non/Malunions	Rigid fixation Maintain/ restore length	Exacting technique Special equipment Extensive exposure May need removal Refracture ; bulky
EXTERNAL FIXATION	Restore length for comminuted/ bone loss Soft tissue & skin injury with loss Infected nonunion	Preserves length Allows access Percutaneous route Manipulation of fracture avoided	Infection/ osteomyelitis Over distraction Neurovascular injury Fracture thro pin holes Loosening

THUMB PROXIMAL PHALANGEAL FRACTURES

EXTRAARTICULAR FRACTURE

Head and neck fractures are treated according to same principles used in treating similar injuries in fingers.

Displaced spiral or oblique fractures are treated by Percutaneous pinning, or by open reduction internal fixation with k-wire or interfragmentary screw.

Transverse fractures angulate apex volarly secondary to pull of Thenar intrinsics on proximal fragment and EPL on distal fragment. Closed reduction is usually stable. Angulation in lateral plane of 20-30 deg is unacceptable. Open reduction internal fixation through dorsal approach is needed.

Most common thumb fracture in child is Salter Harris type 2 Epiphyseal fracture of proximal phalanx. This is managed by closed reduction with MP joint fully flexed to stabilize the proximal fragment while medial and lateral angulation is corrected. Immobilization is done in thumb spica cast.

INTRA ARTICULAR FRACTURES AND AVULSIONS

Intraarticular fractures of IP or MP joints may be single fragment or may be significantly comminuted. Ideally articular congruity should be restored. If symptomatic arthritis ensues MP or IP Arthrodesis can be accomplished with little functional impairment.

A displaced Salter Harris type 3 may require open reduction to restore epiphyseal continuity and correct deformity.

Avulsion fractures of Ulnar base of proximal phalanx usually represent disruption of Ulnar collateral ligament (gamekeeper or skier thumb). If the fragment is displaced more than 2mm then stability need to be surgically restored. If the fracture fragment is small or breaks during fixation, the ligament can be reinserted with pull out wire. Larger fragment can be fixed with k-wire, interfragmentary wire, or 1.5mm lag screw. Immobilization is done with Transarticular k-wire and thumb spica cast immobilization.

COMPLICATIONS OF PHALANGEAL FRACTURES

MALUNION

Malunion is common bony complication of phalangeal fractures and has been sub classified:

- **a.** Malrotation
- **b.** Volar angulation
- **c.** Lateral angulation
- **d.** Shortening

MALROTATION

It is usually seen after oblique or spiral fractures of proximal phalanx. It may be difficult to assess radiographically and may also not be appreciated with digit held in extension. Therefore, having the patient make a fist and looking for digital overlap best way to assess malrotation. Small amount of malrotation may be acceptable to many patients. Significant malrotation may result in functional impairment, pain from joint malalignment and diminished grip strength. Osteotomy is usually required through phalanx or metacarpal.

Phalangeal Osteotomy offers advantage of correcting Malunion at its site of origin, allows for simultaneous correction of angulatory deformities, and permits concomitant soft tissue procedures

Types of Osteotomy:

A: Step cut - fixation with plate or k-wire

B: Transverse – fixation with ASIF screws or k-wire

These are done using power saw with thin blade

Metacarpal Osteotomy through metacarpal base (weckesser) can correct 18-19 degrees angulation index middle and ring and 20-30 degrees in little. Drawbacks are amount of rotational correction is limited to 25 –30 deg and multiplanar correction is not possible. Further Tenolysis and Capsulotomy needs separate approach at site of fracture.

VOLAR ANGULATION

Malunion with angulation greater than 25-30 deg results in pseudo clawing. This deformity results in:

a. Compromise dexterity

b. Aesthetically unacceptable

c. Result in PIP flexion contracture

This deformity is managed by open or closing wedge Osteotomy (apex, dorsal, volar, base) and fixing with k-wire, interosseous wire, or plate and screw fixation.

Closing wedge osteotomy is simpler than open wedge Osteotomy as it does not require intercalated bone graft. If shortening is a concern then open wedge Osteotomy with insertion of wedge shaped graft is indicated.

LATERAL ANGULATION

This is corrected in a similar way to volar angulation using oscillating saw or power burr. Malrotation and volar angulation occurring concomitantly need careful planning and identification of individual components.

SHORTENING

This can occur following comminuted fracture that is allowed to heal in collapsed state, or following a long spiral fracture. Restoration of phalangeal length alone is rarely indicated due to risk of Osteotomy and graft. When there is a concomitant rotatory or angular deformity, Diaphyseal Osteotomy with intercalated graft is indicated.

Occasionally spiral fracture of proximal phalanx healing in shortened position may produce a distal spike that protrudes in Retrocondylar space of PIP joint and acts as flexion block. Digital flexion can be restored by removing the spike through volar approach.

Care should be exercised as overzealous bone removal can lead to

a. Iatrogenic fractures

b. Avascular necrosis of head fragment

INTRA ARTICULAR MALUNION

Unreduced condylar fractures that extend into PIP joint may produce pain, angulatory deformity, limited mobility, and ultimately degenerative arthritis.

Treatment options: ***corrective Osteotomy Arthrodesis, and Arthroplasty***

Corrective Osteotomy through old fracture site and fixation with k-wire or Interosseous wires improves range of motion and relief of pain (***Light***). In younger patients this is preferred to Arthrodesis or Arthroplasty.

<u>NONUNION</u>

This is uncommon except in cases of segmental bone loss. Delayed union is often seen. Nonunion cannot be diagnosed until one year has elapsed (***Smith & Rider***). Operative intervention is advocated 4 months after injury as additional immobilization is likely to cause significant stiffness ***(Jupiter et al).***

Management is by Refixation with plate and screw fixation or k-wire with initiation of active motion 2-3 weeks following fixation ***(Jupiter et al, Wray & Gunk).***

Equally as important as fixation is surgical resection of nonunion – fibrous tissue must be removed until fracture ends are freshened. If resultant gap produces unacceptable shortening intercalated Corticocancellous bone grafting is indicated. Plate fixation allows for concomitant Tenolysis and Capsulotomy when indicated.

<u>LOSS OF MOTION</u>

Diminished motion may be the result of Tendon Adhesions, Capsular Contracture, Intraarticular Incongruity, Arthrofibrosis, and Bony Ankylosis.

Contributing factors are:

a. Immobilization greater than 4 weeks

b. Associated joint injuries

c. More than one fracture per finger

d. Crush injury

e. Soft tissue injury & extent of involvement of tendon and nerve

Treatment of stiffness should begin with

a. Comprehensive program of hand therapy – active and passive mobilization with dynamic splinting.

b. Compressive garment for swelling

When there is a plateau in motion and soft tissue induration surgical intervention can be considered. Tenolysis and Capsulotomy should be individualized (Schneider). It is done under Local Anesthesia with sedation. Initially extensor Tenolysis over proximal phalanx followed by dorsal PIP Capsulotomy if PIP flexion is limited (< 90deg). Patients are asked to flex – if passive flexion exceeds active flexion flexor Tenolysis is performed.

When severe contracture or stiffness exists then PIP Arthrodesis or ray deletion is only option.

INFECTION

Infection after fracture treatment is rare (2.04 –11 %). It usually occurs after open injury when there is associated soft tissue injury, comminuted fracture or contamination. Fractures are classified into 2 types:

Type 1: infection rate – 1.4%

- **a.** Clean wound without significant contamination or delay in treatment
- **b.** No significant systemic illness

Type 2: infection rate – 14%

- **a.** Gross contamination (animal bite, grossly dirty, or barnyard injuries)
- **b.** Delay in treatment greater than 24 hrs
- **c.** Significant systemic illness

Although it has been prove that irrigation and Debridement are adequate treatment, it is preferable to employ prophylactic Antibiotics for open fractures. One dose of 1st generation Cephalosporin is given in emergency room and continuation for 24 hrs. For type 2 wounds addition of Aminoglycoside and Penicillin is recommended.

Treatment of infected fractures – Goals are

a. Eradicating sepsis -- Debridement & appropriate antibiotics

b. Obtaining fracture union –stabilization with mini external Fixator, Bone grafting after eliminating infection

c. Regaining a functional extremity

Significant phalangeal Osteomyelitis is difficult to eradicate. After several procedures final result is often painful, stiff and useless digit where amputation may be only answer.

FLEXOR TENDON RUPTURE OR ENTRAPMENT

It is an uncommon complication and is usually iatrogenic following percutaneous pinning. Rarely volarly angulated fracture and laceration of FDS causes tendon entrapment between bone ends, resulting in cyst in bone and poor flexion of digit.

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