

A Comparative Study of Soft Tissue Cover in Compound Lower Limb Trauma at an Interval of a Decade

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Abstract: Introduction: Compound lower limb trauma needs to be covered with flaps. The defects of lower limb are divided into upper, middle and lower third defects. Different flaps are described based on the site of the defect. Aim: To study the pattern of compound lower limb trauma and the flap options for different defects of the leg at an interval of a decade. Material and Methods: 32 patients with compound lower limb trauma were given flap cover between 2002 and 2005. Another 82 cases have been given flap cover between 2012 and 2015. Comparison of the pattern of compound limb trauma and flap cover is done. Discussion: For upper third leg defects, Gastrocnemius muscle and myocutaneous flaps have been the workhorse then, a decade ago and it is the same now. Propeller & Transposition flaps have been tried in the recent past. For middle third defects, Gastrocnemius myocutaneous, Soleus, Transposition, Cross leg and free flaps were used, while for lower third defects Reverse Sural artery, Fascio-cutaneous and Free flaps are commonly used. Use of Propeller and free flaps are on the rise now. Conclusions: Propeller flaps are an alternative for free flaps in middle and lower third defects in set-ups with infrastructural and human resources constraints. Vastus lateralis as a free flap can be a reasonable alternative in delayed cases.

Keywords: compound defects, flaps, debridement, open fracture, marginal necrosis and limb salvage

1. Introduction

The priorities of management of compound lower limb trauma are skeletal stabilization, restoration of vascular continuity and provision of stable skin cover. External fixator, is the choice in stabilizing the fractures in the Compound leg trauma. Compound lower limb trauma has been classified as below.

Table 1: Gustillo's Classification

Type	Description
I	Open fractures with wound <1cm
II	Open fractures with wound >1cm without extensive soft tissue damage
III	Open fractures with extensive soft tissue damage
III A	III with adequate soft tissue coverage
III B	III with soft tissue loss with periosteal stripping and bone exposure
III C	III with arterial injury requiring repair

Management of Compound Fractures

- Irrigation and debridement
- Definitive wound management
- Primary closure
- Delayed primary closure
- Vacuum assisted wound closure (VAC)

If primary closure of the wound without tension is not possible, alternatives are (i) Relaxing incisions (ii) Skin grafts (iii) Biological dressings and (iv) Flaps.

For upper 1/3rd of leg with open fractures, muscle flaps are the choice.

For the middle 1/3rd of leg with open fractures, fascio-cutaneous flaps are options and for the open fractures in the lower 1/3rd of leg, the options are cross-leg flaps, distal Sural neuro-cutaneous flaps and micro-vascular flaps.

Most of the defects of foot too, are better addressed by the flaps from the leg, or by free flaps rather than the flaps from the leg per-se, though flaps like Flexor Hallucis Brevis muscle flap, Abductor Digiti Minimi muscle flap and medial plantar flap are described.

Though primary cover is ideal, it may not be feasible in all cases even in the best of Institutions, especially so in tertiary care public hospitals like ours as patients are usually referred to us after considerable delay. Hence the needs for alternatives, in the form of Delayed flap cover.

Fascio-cutaneous flaps consist of skin, subcutaneous tissue and deep fascia. Blood supply of fascio-cutaneous flaps in the leg comes from:

1. Septo-cutaneous perforators that arise from Posterior tibial artery – medially.

The medial septo-cutaneous perforators emerge through Soleus in the upper 3rd and between soleus and FDL in the lower 2/3rd leg.

Anterior tibial artery – Anterolaterally, Peroneal artery-Posterolaterally. The posterolateral perforators emerge between Peroneous longus & Soleus in the upper 3rd & between Soleus & FHL in the lower 2/3rd. The anterolateral perforators emerge between Peroneous and extensor muscles.

2. Musculo-cutaneous perforators, coming through both Gastrocnemii.

The pre-operative surface marking of septo-cutaneous perforators can be done as their position is constant in the leg. The position of the perforators is given below.

<i>Vessel location</i>	<i>Posterior tibial (Distance from Medial Malleolus)</i>	<i>Peroneal (Distance from Lateral malleolus)</i>	<i>Anterior tibial</i>
N1	4.5 cm	4-10 cm	2cm from ATA
N2	6 cm	10-13 cm	
N3	9-12 cm	15-20 cm (L.M)	
N4	17-19 cm	5-6 cm (F.H)	
N5	22-24 cm		

Selection of fascio-cutaneous flaps depends on the zone of injury in the leg.

Upper 1/3rd leg: Proximally based fascio-cutaneous flaps based on the perforators of Posterior tibial, Peroneal and Anterior tibial arteries.

Middle 1/3rd leg: Both proximally and distally based fascio-cutaneous flaps based on perforators of Posterior tibial, Anterior tibial and Peroneal (Ipsilateral or cross-leg flaps) and musculo-cutaneous perforators of the Gastrocnemii.

Lower 1/3rd leg & ankle:

1. Distally based fascio-cutaneous flaps based on the perforators of Posterior tibial and Peroneal-(Ipsilateral or cross-leg flaps).
2. Distally based Sural neuro-cutaneous flap.

Distally Based Sural Neuro-Cutaneous Flap

Distally based Sural neuro-cutaneous flap is an excellent option for covering defects of the lower third of the leg. It allows rapid, reliable coverage of defects extending as far distally as the mid foot.^(1,2)

Basis of Vascular Anatomy of Reverse Sural Artery Flap

The Median superficial sural artery, which runs in conjunction with the Medial sural cutaneous nerve, and a series of two arteries accompanying the Short saphenous vein provide the axial pattern blood flow to the superficial plexus, which allows elevation of this flap. These axial pattern vessels make a series of interconnections with perforating vessels in the region of the lateral malleolus.^(3,4)

Surgical Anatomy

The median superficial sural artery generally takes its origin from the popliteal artery, courses posteriorly for 2 to 3 cm before joining the medial sural nerve, descends between the two heads of the gastrocnemius muscle, and then follows the lateral edge of the Achilles tendon. The artery courses alongside the sural nerve to the distal one third of the leg, anastomosing with the supramalleolar branch of the peroneal artery at about 5 cm above the tip of the lateral malleolus and posterior tibial artery and in rare instances with the lateral tarsal artery. This artery gives off much arteria nervorum to the nerve with septocutaneous perforators. Usually, paired venae comitantes travel with the median superficial sural artery.

The medial sural nerve descends in close association with the lesser saphenous vein. This nerve is supplied by the median superficial sural artery in the proximal one third of the leg. The distal two thirds is supplied by fascio-cutaneous branches of the peroneal artery. In addition, the Sural nerve also has intrinsic blood supply.

The lesser saphenous vein takes its origin from the lateral extension of the dorsal venous arch of the foot. It passes posteriorly to the lateral malleolus accompanied by the Sural nerve. At the junction of the distal and middle thirds of the leg, the lesser saphenous vein locates more medially and follows the course of the Sural nerve.⁽⁵⁾

The flap can be raised anywhere in the lower two thirds of the leg. The pivot point of the pedicle must be at least 5 cm above the lateral malleolus to allow anastomosis with the peroneal artery. At the upper border of the flap, the Medial Sural nerve, median superficial sural artery and the Short saphenous vein are ligated, divided and included in the flap. The inclusion of the lateral Sural nerve may reduce the incidence of marginal necrosis. The mesentery-like connections of the above structures with the deep fascia need to be preserved. This mesentery-like structure contains small perforator vessels that run into the deep fascia and possibly ramify with the fascial vascular plexus, which accounts for the reliability of this distally based flap despite its huge dimensions. This fact also supports use of the term “Neurofascio-cutaneous” to identify these flaps.⁽⁶⁾

Cross-Leg Skin Flap

The cross- leg skin flap, a direct bridge flap from one lower extremity to the other, is a standard method of providing flap of skin to resurface defects of the lower limb.

Conventional cross-leg flap does not include the fascia and the ratio of 1:1(Length: Breadth) is adhered to, while harvesting it. It is mostly harvested in the upper third or middle third of leg. The base of the flap should stop at-least 1.5 cm away from the border of the bone and the flap can extend into the calf till the midline. If the fascia is included in the flap, it can be extended to include up-til 2/3rd of the circumference of the calf. The cross leg flaps can be raised on the perforators on either the medial or lateral side of the leg and these flaps can be raised much beyond 1:1 (Length: Breadth) ratio. It is ideal to incorporate the fascia in all the

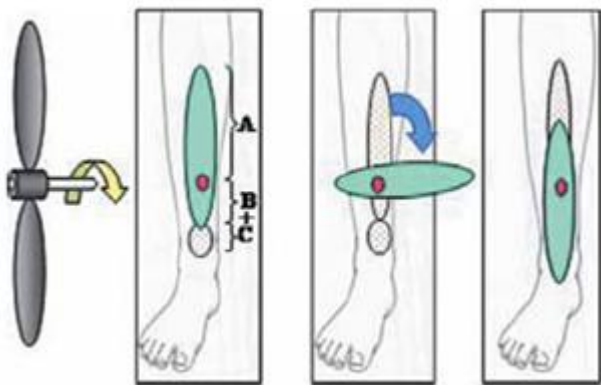
cross-leg flaps. The donor leg of the flap should be free of scars, if cross leg flap is being contemplated from that leg.

Perforator Flap

The perforator vessel is the one where the source artery is deep and the branch that carries blood directly to fascio-cutaneous tissues in its course to reach the skin passes through the overhanging muscular tissue without exclusively following the intermuscular septum. Because of the anatomic properties of circumflex femoral system, the Anterolateral thigh flap is a perfect model with which to demonstrate the differences between perforator flaps and the other types of flaps. The main pedicle provides numerous septo-cutaneous and musculo-cutaneous branches to the surrounding. This permits harvest of various compositions of flaps based on either septo-cutaneous vessels or musculo-cutaneous perforators.^(7,8,9)

Propeller Flap

Distally based perforator flap has been given the nickname of propeller flap on account of the fact that it rotates around a single perforator like the 2 blades of a propeller.



It is a pedicled, islanded fascio-cutaneous flap based on a single perforator, which can be useful for reconstruction in many areas of the body.

In Lower limb reconstruction, the propellar flap has been particularly useful in allowing defects on the most awkward distal third of the leg to be covered reliably.

Muscle Flaps Available for Defects of Leg

A) Local Flaps

- 1) Gastrocnemius
- 2) Soleus

Gastrocnemius Flap

Generally, the muscle alone is transposed, and if any further skin coverage is required, it is accomplished with a split-thickness skin graft. This leaves a relatively insignificant donor-site contour deformity, in contrast to use of myo-cutaneous flap which results in a large skin-grafted mid calf.⁽⁹⁾

Indications: As a muscle flap, the medial head can cover wounds of the knee and upper third of the tibia. The lateral head can be applied to upper lateral leg and knee wounds of somewhat lesser dimensions.

As a musculo-cutaneous flap, the medial Gastrocnemius, range of coverage will include the lower thigh, knee, and upper two-thirds of the tibia.

The medial and lateral Sural arteries provide independent blood supply to the two muscle heads. These vessels arise from the Popliteal artery at the level of the knee joint. Each courses a few centimeters with its venae-comitantes before entering the anterior aspect of the proximal muscle belly with the innervating branches of the Tibial nerve. The vessels then pass down the longitudinal axis of the muscle bellies. This vascular arrangement is constant and effectively constitutes the sole supply of the muscle, making it ideally suited for use as a flap. The independent neurovascular supply of the two muscle bellies allows them to be used as separate muscle and musculo-cutaneous flaps.

Soleus Muscle Flap

The Soleus muscle provides several reliable flaps that are frequently one of the first choices for repair of defects between the knee and ankle.

Indications: These flaps are used to cover defects in the middle third (Soleus and hemisoleus muscle) and distal third (Soleus musculo-cutaneous and reverse medial hemisoleus muscle) of the leg that cannot be covered with skin grafts and are not so massive as to require large free or cross-leg flaps.

The vascular supply is from Popliteal, Posterior tibial, and Peroneal vascular pedicles to the distal lateral belly, and segmental posterior tibial pedicles to the distal medial belly.

B) Distant Flaps

- 1) Micro-vascular flaps
- 2) Cross-leg flaps
- 3) Transfer of flaps using wrist as carrier

Cross-leg flaps are available but have generally been supplanted by either local muscle flaps or micro-vascular composite tissue transplantation techniques.

Micro-vascular transplantation has made a significant impact on reconstruction of the lower leg. Extensive defects are successfully reconstructed by using muscle such as the Latissimus Dorsi, Gracilis, Serratus and Rectus abdominis. In certain individuals, micro-vascular transplantation is not possible. For such patients, alternative methods of reconstruction include the use of random or fascio-cutaneous cross-leg flaps.

Earlier the transfer of Abdominal or Groin tubed pedicled flaps using wrist as carrier to resurface knee, leg or ankle defects, in staged procedures, was used before the advent of the present day Pedicled/Microvascular flaps.

Foot Flaps

Flexor hallucis brevis muscle flap: The whole of the muscle can be used by itself to fill defects in the anteromedial sole of the foot, such as perforating ulcers.

Flexor digitorum brevis muscle flap: This is used exclusively to cover the defects of the heel.

Abductor digiti minimi muscle flap:

Medial plantar flap: It is used to cover the entire plantar surface of the heel.

It is used to cover the defects of the heel and the lateral surface of the ankle joint and lower leg.

2. Aim

To study the pattern of compound lower limb trauma and flap options for different defects of the leg at an interval of a decade.

3. Material & Methods

This study compares the pattern of the compound lower limb trauma and the different flap covers given for the 32 cases studied at Osmania General Hospital, Hyderabad, between 2002 and 2005, in the Department of Plastic Surgery, versus the same for the 82 cases operated at Gandhi Hospital, Secunderabad between 2012 and 2015.

The outcome of the flaps, according to age, site, time and type of flaps have been analyzed and compared between the two groups. Role of newer flaps like propeller flaps and free flaps was studied.

Inclusion Criteria

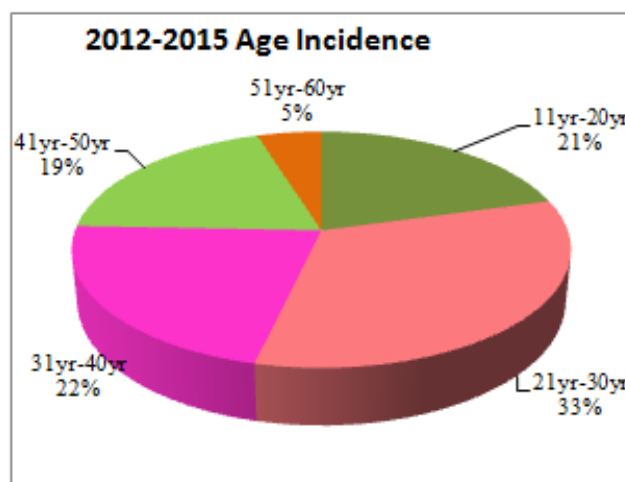
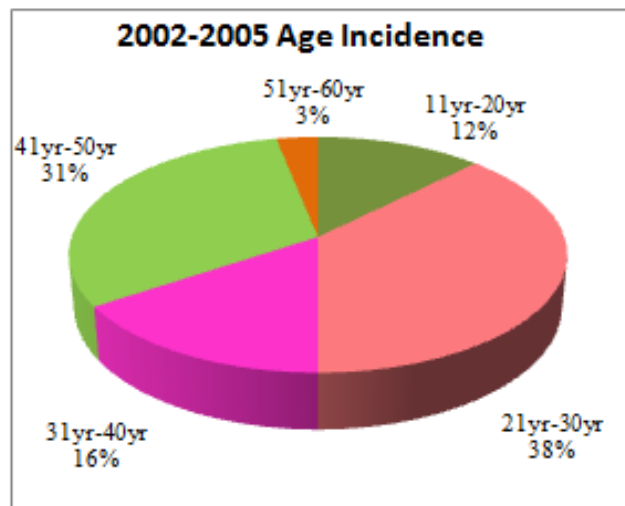
Isolated compound lower limb injuries with or without fractures.

Exclusion Criteria

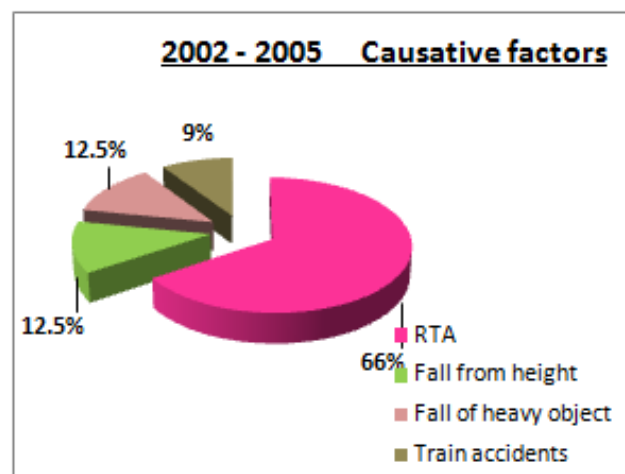
Patients with polytrauma
 Patients of <10 years of age and >60 years of age
 Patients with significant medical disorders.

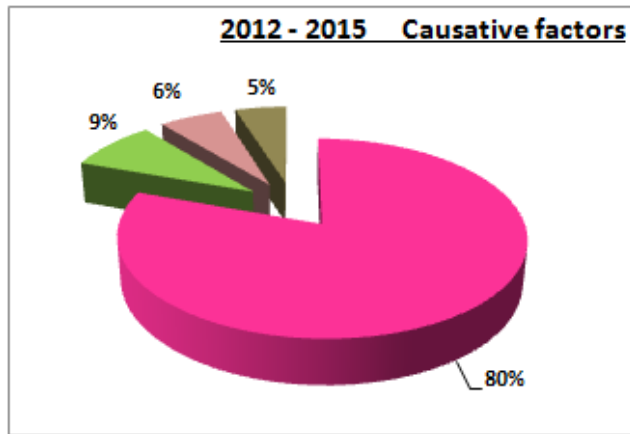
4. Observations

Graph 1 shows the pattern of age distribution of the patients with compound limb trauma. The incidence of the trauma was mostly in the second, third and fourth decades, with the maximum being in the third decade and it has been so in both the groups.

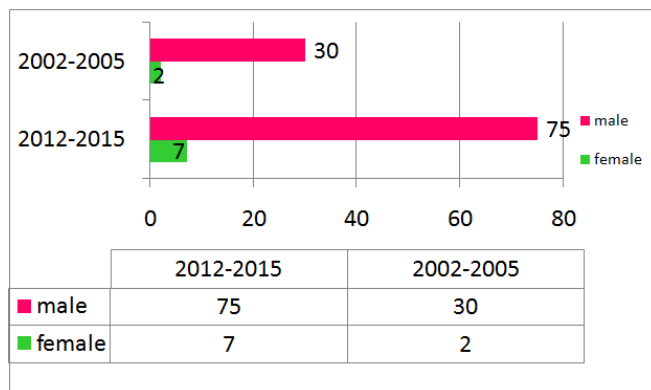


Graph 2 shows the causative factors of the trauma. Road traffic accidents, fall from height, fall of heavy objects and train accidents were the causes with the road traffic accident being the leading one, in both the groups.

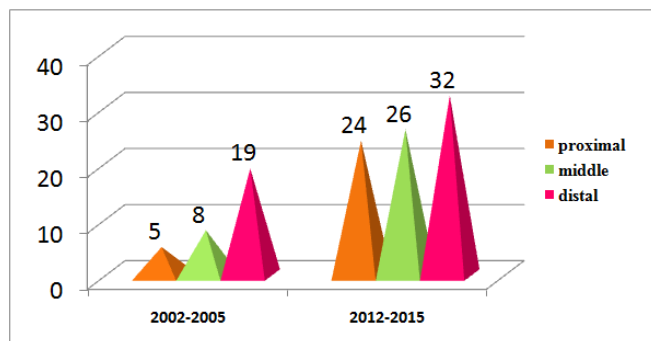




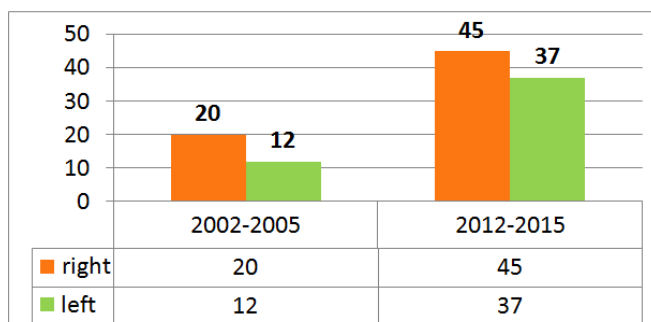
Graph 3 shows the gender distribution of the trauma, with males being commonly involved, in both the groups.



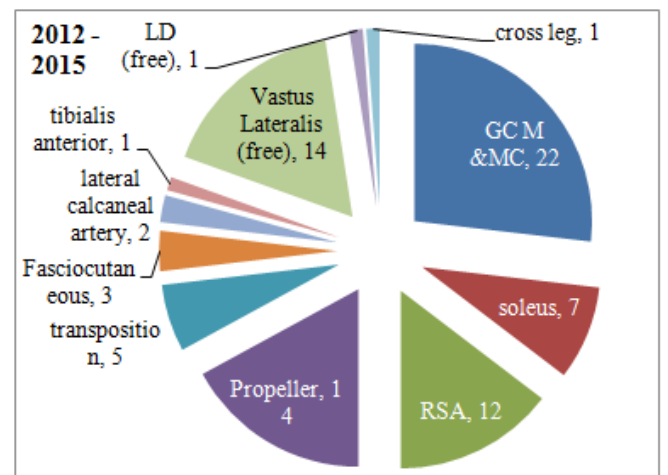
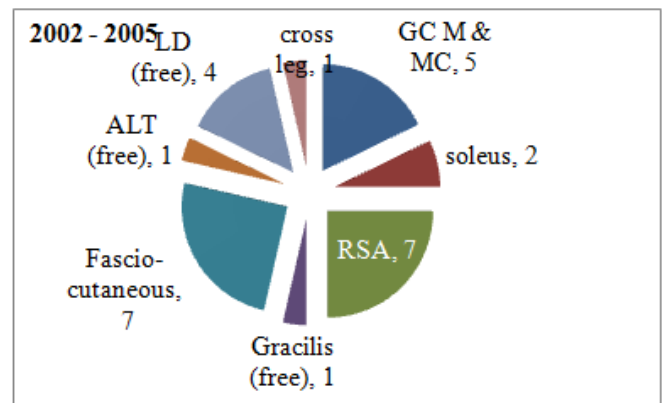
Graph 4 shows the distribution of the site of the defect with the lower third being the common involved site in both the groups.



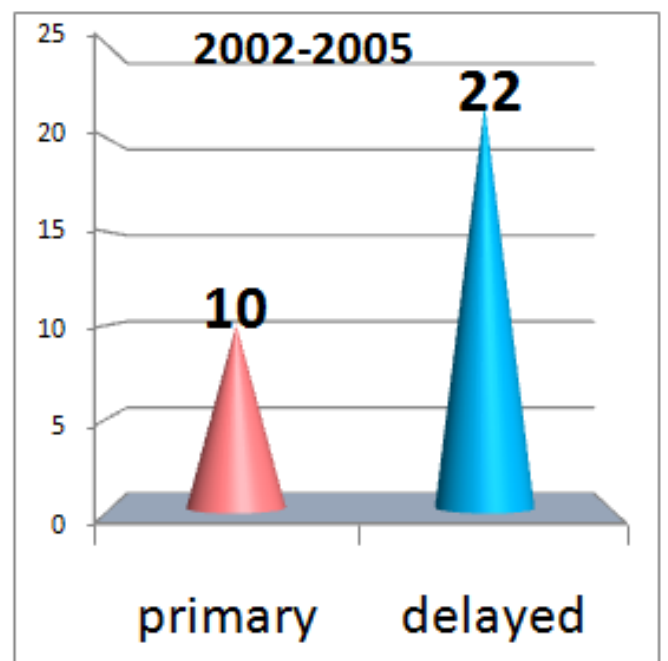
Graph 5 shows the side of the defect on the lower limb, with the right sided involvement being more common in both the groups.



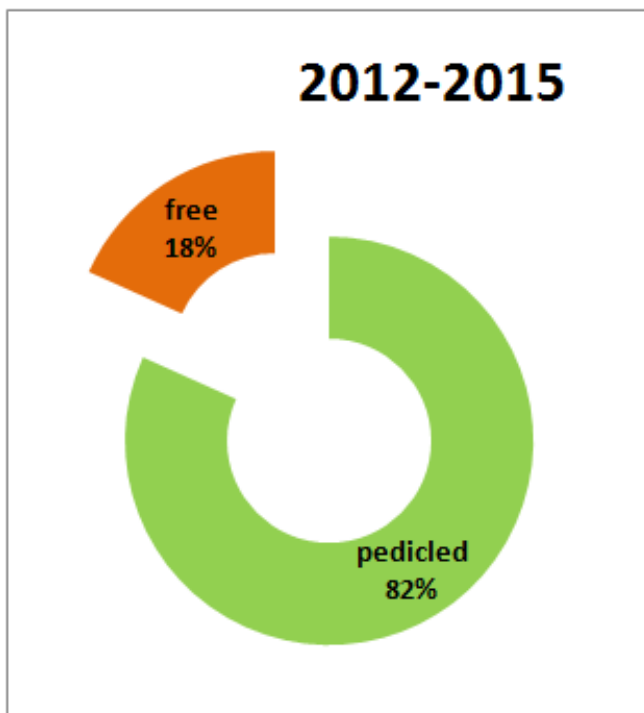
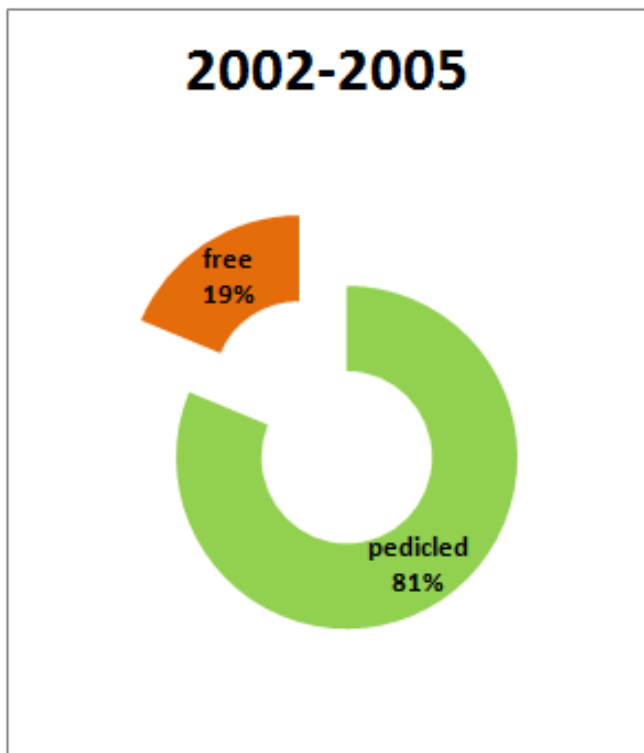
Graph 6 shows the pattern of types of flaps done. In the Group operated between 2002 and 2005, the fasciocutaneous flaps were the predominant flaps. In the Group operated between 2012 and 2015, the other flaps like Propellar, Lateral Supramalleolar flaps, Transposition flaps were more often done.



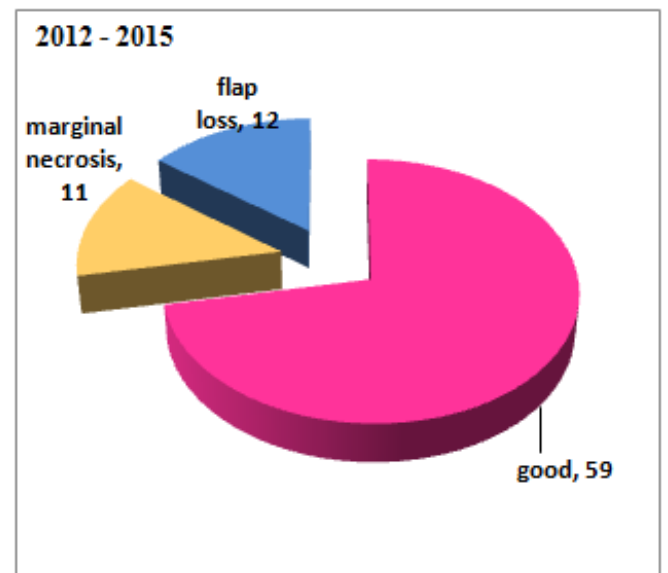
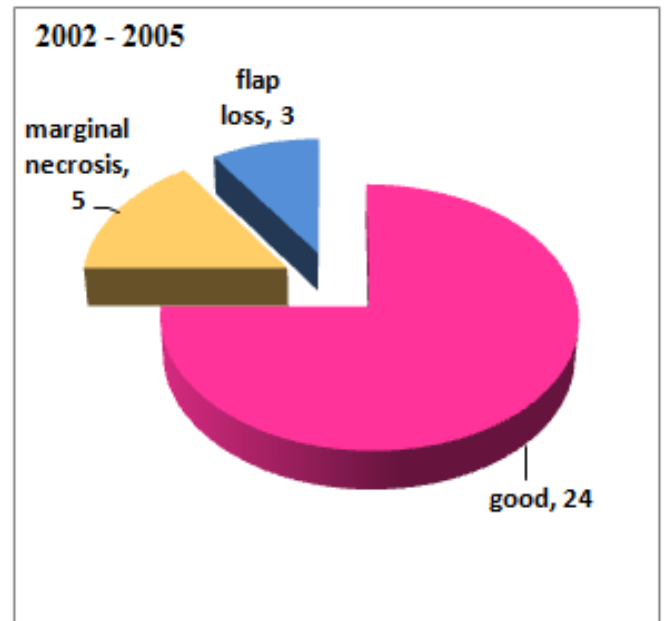
Graph 7 shows the pattern of the time of flap cover, with delayed pattern of flap cover being the dominant method.



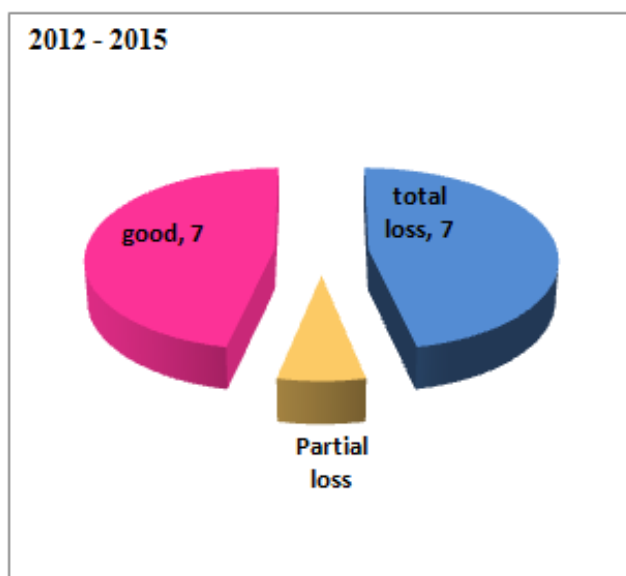
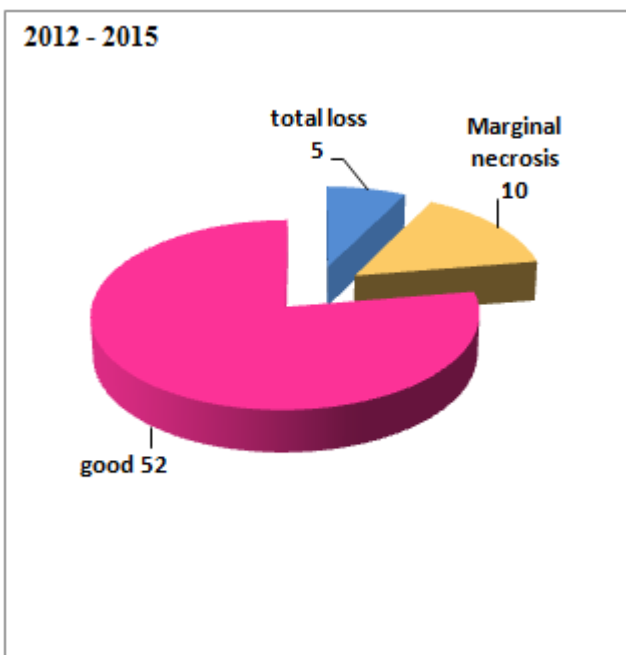
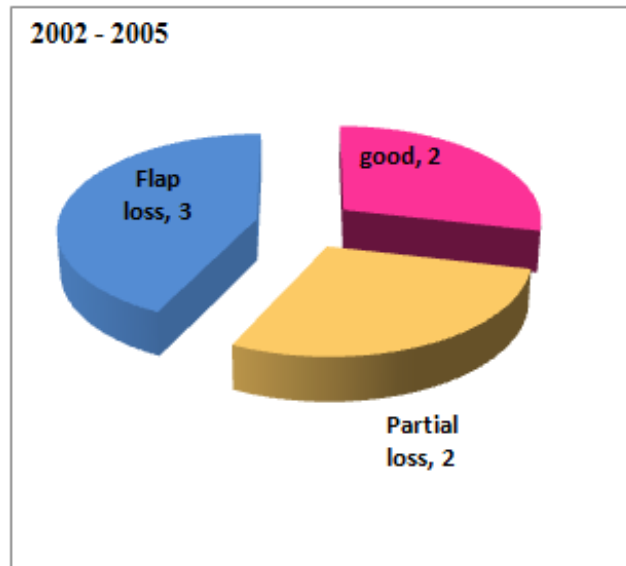
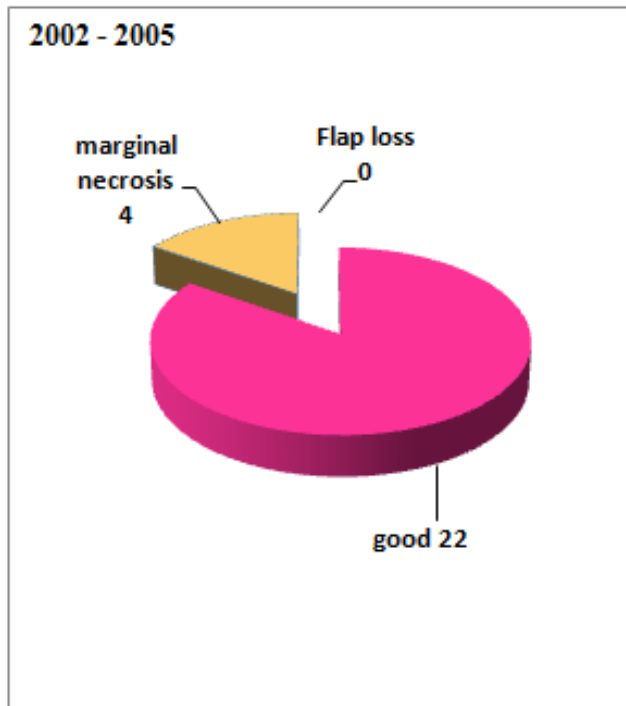
Graph 8 shows the pedicled and free flaps in both the groups, with the pedicled flap cover as the major types of flaps then and now.



Graph 9 shows the outcome of the flap cover. Incidence of flap loss has been little high in the group operated of late, and it is due to more number of free flap covers.



Graph 10 shows the outcome of the pedicled flap cover. There have been flap losses in the second group, because of larger group with some of them having got operated upon by the residents.



Graph 11 shows the outcome of the free flap cover. The outcome of free flap has improved in the second group.

Table 1 shows the types of flaps used for the upper third defects. Gastrocnemius was the major flap used then and now, but Propeller flaps have been used in the recent past.

Type of flap between 2002 and 2005	Total	Result
Gastrocnemius muscle and myocutaneous flap	5	Good

Type of flap between 2012 and 2015	Total	Result
Gastrocnemius muscle and myocutaneous	18	Good
	Marginal necrosis	4
Transposition	3	Good
Propeller	3	Good
	Flap loss	1

Upper Third Defects



1. Compound Wound in Upper Third of Right Leg



2. Post Op. Gastrocnemius Myocutaneous Flap Cover



3. Compound Wound in Upper Third of Right Leg



4. Post Op. Propeller Flap

Table 2 shows the flaps provided for the middle third defects. In the groups operated between 2012 and 2015, propellar flaps were used along with the other flaps which were used in the group operated between 2002 and 2005.

Type of flaps between 2002 and 2005		Results
Soleus – 2		Good – 2
Fascio-cutaneous – 3		Good – 3
Cross -leg – 1		Good – 1
Free ALT – 1		Flap loss – 1
Free LD - 1		Flap loss - 1
Type of flaps between 2012 and 2015		
Propeller – 8	Good	6
	Flap loss	2
Soleus – 8	Good	6
	Marginal necrosis	1
Gastrocnemius myocutaneous flap – 4	Good	3
	Flap loss	1
Transposition – 2	Good	2
Cross -leg – 1	Good	1
Fascio-cutaneous flap – 4	Good	3
	Marginal necrosis	1



5. Middle Third Defect



8. Exposed Tibia Over Middle Third of Left Leg



6. Intra Op. Propeller Flap



7. Post – Operative



10. Post Op. Status of Gastrocnemius Muscle Flap Covered with Skin Graft



11. Middle third defect



12. Intra operative



13. Postoperative

Table 3 shows the flap cover for the lower third defects. Free flaps, Propellar flaps have been used in group operated between 2012 and 2015.

Flaps between 2002 and 2005			
RSA	7	Good	4
		Marginal necrosis	3
Fascio-cutaneous	8	Good	7
		Marginal necrosis	1
LD (free)	4	Good	2
		Marginal necrosis	2
Gracilis (free)	1	Flap loss	1

Flaps between 2012 and 2015			
RSA	12	Good	11
		Marginal necrosis	3
Vastus lateralis (free)	14	Good	6
		Marginal necrosis	1
		Flap loss	7
LD (free)	1	Good	1
Lateral calcaneal flap	2	Good	2
Propeller	3	Good	2
		Flap loss	1



14. Defect Over Medial Aspect Of Right Ankle



17. Compound Defect Over Lower Third of Right Leg



15. Reverse Sural Artery Flap Cover



18. Intra Op. Photo of Propeller Flap



16. After Division and Inset of Reverse Sural Artery Flap



19. Post Op. Status of Propeler Flap



20. Compound Defect Over Left Heel



23. Free Latissimus Flap Cover for Compound Defect Over Right Ankle



21. Intra Op. Lateral Malleolar Flap



24. Post Op. Status



22. Post Op. Status



25. Two Weeks Later

Table 4: The comparative study of the outcome of the flaps

	Asif Zubair Bhatti et al lower leg flap comparison between Free vs local flaps IJPS – 2007 vol.3, No.3 50 cases	Our study between 2002 – 2005 32 cases	Our study between 2012 – 2015 82 cases
Pedicle flap	Total loss – 1/26 (3.8%) Partial loss – 2/26 (7.6%)	Total loss – 0/26 Partial loss – 4/26 (15%)	Total loss – 5/67 (7.5%) Partial loss – 10/67 (15%)
Free flaps	Total loss – 2/24 (8.3%) Partial loss – 2/24 (8.3%)	Total loss – 3/7 (42%) Partial loss – 1/7 (14%)	Total loss – 7/15 (46%) Partial loss – 1/15 (6%)
Good	43 cases (86%)	24 cases (75%)	59 cases (72%)
Partial loss	04 cases (8%)	05 cases (15.6%)	11 cases (13%)
Total loss	03 cases (6%)	03 cases (9.3%)	12 cases (15%)

5. Discussion

Compound lower limb trauma is on the rise. The various causes are the road traffic accidents, fall from height, fall of heavy objects and train accidents. The commonly affected second, third and fourth age groups are those who move around actively and at speed and who are the bread winners of the family. Males still are the commonly involved gender in the compound limb trauma. Right sided involvement is more than that of the left. This pattern of observation has not changed over a period of a decade, but the number of cases has increased almost two fold. 63% of these compound leg traumas were found to be with compound fractures. The rest of 37% did not have fractures.

Both bone fractures were seen in nearly 80% of these compound fractures.

For upper upper 1/3rd of leg with open fractures, muscle flaps continue to be the choice.

For the middle 1/3rd of leg with open fractures, fascio-cutaneous flaps are the preferred options and for the open fractures in the lower 1/3rd of leg, the options are cross-leg flaps, distal Sural neuro-cutaneous flaps and micro-vascular flaps. Most of the defects of foot too, are better addressed by the flaps from the leg, or by free flaps.

Over a period of decade from 2002 to 2015, though the above flaps are still being adopted, newer flaps like Propeller flaps, Lateral Supra malleolar flaps have been on the rise, which has been observed in this study. There has been a rise in the usage of free flaps with newer free flaps like Anterolateral thigh flaps, Vastus lateralis flaps being tried instead of the conventional Latissimus dorsi flap in each case. The outcome of the free flap cover too has improved with the passage of time.

The outcome of the flaps in the period between 2002 and 2005, and now in the period between 2012 and 2015, are similar and on comparison with the study by Asif Zubair Bhatti⁽¹⁰⁾ the outcomes needed improvement, emphasizing the need to be improve on the planning, handling and care of the flaps.

The outcomes in free flaps in the period between 2002 and 2005 and now between 2012 and 2015 too need to improve in comparison to those in Asif Zubair Bhatti. The reason could be that in our study the free flaps were given on delayed basis with the recipient vessel not so suitable and perhaps the re-explorations need to be undertaken to salvage the flaps, which have not been possible in the infrastructural setup of our institution.

6. Conclusions

- Young and middle aged males were the commonly affected people in compound leg trauma.
- Road Traffic accidents were found to be the common cause of compound leg trauma.
- Most of these compound fractures were Gustilo Type IIIB.
- Lower third leg injuries were more common than the middle third and upper third injuries.
- Muscle flaps still continue to be the choice for upper third, fascio-cutaneous for the middle third, reverse sural artery flap and free flaps for the lower third and around ankle.
- Newer flaps like Propeller flaps have a place in any of the third of the leg, Lateral Supra malleolar flap have a role in the smaller defects on the lower third of the leg and around ankle. Newer free flaps like Anterolateral thigh flaps, Vastus lateralis flaps are being tried instead of the conventional Latissimus dorsi flap which are Perforator based flaps.

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