ORIGINAL ARTICLE

Stump-plasty: An Operation Born of Necessity in Gaza

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Abstract

Aim and objective: The most recent wave of lower limb amputees in Gaza arises from ballistic injuries sustained during protests. This study evaluates the requirement for surgical revision of these mature stumps to allow prosthetic fit and mobility.

Materials and methods: A multidisciplinary team (MDT) comprising a prosthetist, orthopaedic and plastic surgeons and a physiotherapist screened 104 amputee stumps (103 cases). The 27 cases selected for surgical revision (stump-plasty) are the subject of this study.

The MDT prescriptions of care issued at screening were compared to surgical procedures performed at stump-plasty and the findings. Compliance with the MDT prescription was recorded. Stump issues are identified to propose modifications of primary amputation technique to mitigate future revisions.

Patients' healthcare status was assessed by questionnaire (EQ-5D-L5) at screening, then subsequently post-stump-plasty.

Results: More below-knee amputees (BKAs) than above-knee amputees (AKAs) required stump-plasty. Revisions varied according to the quality of tissue present at the amputation level. AKA revisions addressed bulk and contour issues whereas BKA revisions related to bone prominence, neuroma formation and lack of soft tissue cover. Despite many variations in tissue-targeted procedures being possible, the MDT prescription was followed accurately at surgery.

Suggested modifications at primary amputation to decrease revisions include improved bone tip bevelling at BKA and greater soft tissue reduction at AKA. Severed nerve management needs to be rationalised to reduce primary neuroma formation and neuroma revision at stump-plasty requires consideration to attempt to reduce the recurrent risk. Removal of the fibular remnant in short BKA stumps at primary amputation could mitigate common peroneal nerve hypersensitivity later.

Following stump-plasty, amputees recorded a significantly improved score in three of five dimensions of the EQ-5D-L5 questionnaire: activities, anxiety levels and pain.

Conclusion and clinical significance: Primary ballistic injury dictates the level of amputation and the resultant stump quality.

Issues arising in these complex amputee stumps benefited from measured decisions and specialist care delivered by the MDT. Stump-plasty aims to improve the amputees' prosthetic fit, mobility and health.

Keywords: Ballistic injury, Cohort study, Lower limb amputee, Stump-plasty, Stump revision.

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Introduction

Due to recurrent episodes of conflict in Gaza, young amputees are a visible presence in the general population. The most recent additions to this minority group are amputees associated with the Great March of Return (GMR).[1,2] This group of amputees is characterised by their young age, being mostly males and having sustained a severe ballistic injury to their legs.

Between January and March 2020, all registered amputees from the GMR were invited for assessment. This study was to identify the indications for revision surgery of the mature, post-ballistic amputee stump with the goal of enhancing function and comfort. A multidisciplinary team (MDT) approach was applied to cover all facets of amputee support and care during an assessment.

Our ultimate goal is to recognise how we can maximise patient mobility and quality of life after amputation. We advocate specialist care for complex lower limb amputation stumps that result from ballistic injuries. The promotion of an MDT approach to amputee care is applicable in lower income countries and can make amputation a modality of treatment, not a life sentence of immobility. This first phase of the study was a fact-finding mission to define the present clinical state of amputees and establish areas of future care that need attention.

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Materials and Methods

All lower limb amputees registered during the GMR protests were invited for an MDT assessment. The MDT included a senior prosthetist, an orthoplastic surgical team and a physiotherapist. Psychological support and pain management teams were available as required. This article concerns the 27 cases prescribed stump revision surgery; a combination of procedures to the bone, neural or soft tissues that we collectively termed stump-plasty.

Patient demographics, history of injury, interventions preceding amputation, primary amputation technique and any stump revision surgery prior to screening were recorded. The number of prostheses supplied to date and current prosthetic problems were noted. Patients' written consent for participation in this study and ethical permission was confirmed.

Flowchart 1 demonstrates the algorithm used for patient flow at screening. The prosthetist performs the primary evaluation of both prosthesis and stump. The orthoplastic team assessed the stump and contralateral leg recording any patient concerns. The femoral bone length was measured from the anterior superior iliac spine to the bone tip and tibial length from the knee joint line to the bone tip. A below-knee amputation (BKA) with the tibial length less than 12 cm, or an above-knee amputation (AKA) with femoral length less than 20 cm, was recorded as 'short stumped'. The MDT members discussed the clinical findings, and an individualised patient prescription was formulated recording collective management decisions. Five categories of management were possible (Table 1).

Proposed tissue-targeted revisions to soft tissues, bone or neural tissues were recorded on the MDT stump-plasty prescription.

Flowchart 1: Algorithm of potential patient pathways at MDT screening. The prosthetist performs the first assessment and initiates the flow of amputees through the pathway

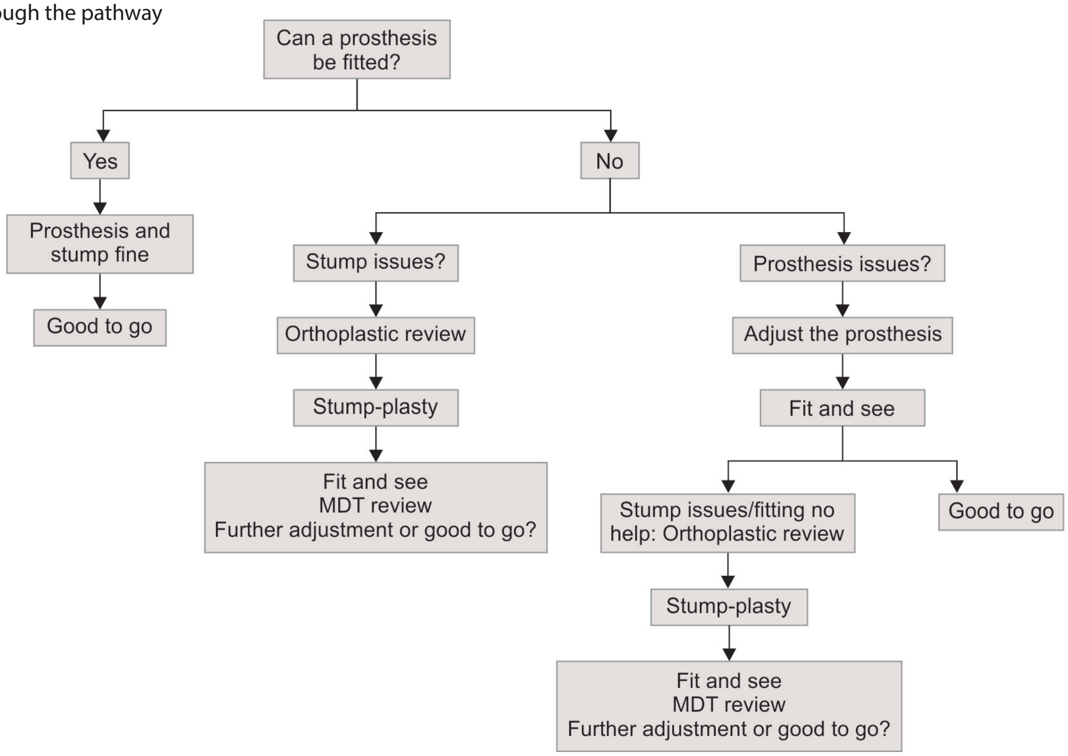

Table 1: Details of the five categories of management plan prescribed to 103 amputees (104 stumps)

Amputee management plan category	*MDT prescription*	*Action required by MDT team*
'Good to go' Stump all good/has a prosthesis	• Surgery: nil • Prosthetist: no adjustment	• Patient: continues as before • Maintenance: follow-up by MDT
Needs first prosthesis Stump all good/fit first prosthesis	• Surgery: nil • Prosthesis: ready for first prosthesis	• Prosthetist: makes a prosthesis • Physiotherapist: mobilises • Maintenance: follow-up by MDT
Needs existing prosthesis adjusted Stump all good/technical issues with the existing prosthesis	• Surgery: nil • Prosthetist: adjusts current prosthesis	• Prosthetist: adjusts/repairs/fits • Physiotherapist: mobilises • Maintenance: follow-up by MDT
'Fit and see' Stump issue present but potentially surmountable by fitting	• Surgery: nil Perceivable stump problem that surgical revision could address • Prosthetist: can modify the prosthesis to mitigate stump issue	• Prosthetist: modifies prosthetic 'fit' • Physiotherapist: mobilises • MDT review: secondary stump-plasty if the prosthetic adjustment has not overcome the issue
Stump-plasty Stump requires surgical revision	• Surgery: stump-plasty to correct physical stump issue • Prosthetist: cannot simply modify prosthesis to mitigate stump issue. Fit after stump-plasty	• Surgeon: primary stump-plasty • Prosthetist: fitting post-stump-plasty • Physiotherapist: mobilises • Maintenance: MDT review to assess stump-plasty outcome

Supplementary digital content 1 (SDC1) expands on the indications and the range of potential surgical procedures for stump-plasty currently available in Gaza. At operation, the surgical team recorded their intraoperative findings and compliance with the original MDT stump-plasty prescription.

The extent of the stump-plasty was categorised as total or partial. A total stump-plasty involves revision of all three tissue elements whereas in a partial stump-plasty less than three elements are revised. The timing of stump-plasty was either primary or secondary. Primary stump-plasty was prescribed for insurmountable stump problems that prevent the fitting of the first definitive prosthesis and are recognised immediately at MDT screening. Secondary stump-plasty occurs when the original MDT prescription fails after a period of prosthetic use and the original management option converts to stump-plasty to correct these issues.

Stump-plasty bony revisions methods fell into 5 variations. Two variations modified the stump tip profile. These included 1) minor bone shortening and bevelling for bone prominence and 2) minor bone shortening to allow soft tissue redistribution. For both of these later revision methods, bone length reduction was a consequence of the procedure rather than the goal. The three other variations of bone revision involved removal of a section of bone: 1) True shortening for excess bone length 2) proximal advancement of the amputation level and 3) excision of the fibular remnant. All 27 stump-plasties were prescribed a soft tissue component to the revision surgery. Two varieties of soft tissue revision were prescribed at stump-plasty:

- Revision of elements impacting stump form and function (scars, stump contour, excessive bulk, tip padding problems and muscle imbalance).
- Removal of 'unwanted extras' including unstable skin grafts, crypts and foreign bodies.

An EQ-5D-5L questionnaire was completed at screening (before the MDT assessment) and repeated 3 months after stump-plasty.[3] This provided a generic measurement of the group's health state using five dimensions (mobility, self-care, usual activities, pain and discomfort and anxiety and depression). Each dimension was scored to five levels of severity. The patient indicates any 'perceived problems' by selecting from levels 1 to 5, where level 1 indicates no problem and 5 indicates an extreme problem. The visual analogue scale (VAS) score recorded the respondents' self-rated health on the day of questioning.

A statistical analysis was performed using R. Data were grouped and cleaned when needed using R libraries 'dplyr' and 'tidyr'. The one-way analysis of variance and Tukey's 'honestly significant difference" method with 95% family-wise confidence level were used for the comparison of means. Fisher's exact test was used to calculate the significance of the association for categorical data when patients were grouped in two different ways. Graphs were generated with R library 'ggplot2'.

Results

Of the 120 amputees registered from the GMR protests, 103 amputees presented for an MDT assessment. All 104 mature stumps resulted from a primary ballistic injury. AKA and BKA were present in almost equal numbers (AKA 51/104, BKA 52/104, hip disarticulation 1/104). Most amputees are male (99%, 102/103).

The following results refer to the management of 18 of 27 patients (26%, 27/104 mature stumps) that were prescribed stump-plasty by the MDT. Eighteen of the 27 stump-plasties have been completed to date. SDC 2 summarises the MDT prescriptions issued and compliance of the surgical team with the prescription for the 18 completed stump-plasties.

Most cases (96%: 26/27) are primary stump-plasties. Only one case was secondary, transferring from the 'fit-and-see' group to replace a primary stump-plasty theatre cancellation. Partial stump-plasty was more frequent (63%: 17/27) than total stump-plasty (33%: 9/27). Only one case in the cohort was prescribed a change of amputation level (4%: 1/27).

All original wounds were closed by the time of MDT screening. Patient demographics and chronology of events relating to amputation are presented in Table 2. The majority of stump-plasty cases received delayed, not immediate, amputations. More BKAs required stump-plasty than AKAs (BKA 63%: 17/27, AKA 37%: 10/27).

Eighty-one percent (22/27) of the amputees agreed to have revision surgery. Sixty-six percent (18/27) of stump-plasties were completed by March 2020. Four cases awaited on a priority waiting list due to delays caused by the COVID-19 pandemic. Five stump-plasty cases did not have surgery in our unit. Four amputees declined surgery, wishing treatment elsewhere. The patient prescribed a change of amputation level from BKA to AKA was considered a 're-amputation' rather than stump-plasty. In accordance with national guidelines, he was referred to a specific governmental unit in Gaza for this surgery.

A bony revision was prescribed to 59% (16/27) of stump-plasties. This was most common in BKA stumps (BKAs 71%, 12/17; AKA 40%, 4/10). The mean preoperative AKA femoral bone length was 27.1 cm (SD [standard deviation] 7.81 range, 17–38 cm). The mean BKA tibial

Table 2: Chronology of events and time intervals between GSW, injury, amputation and screening for patients who are prescribed stump-plasty

Average age and clinical landmark	**Average (SD; range)**
Average age at injury	26.11 years (SD 9.04; range 14–48, median 25 years)
Average age at amputation	26.26 years (SD 8.99; range 14–48, median 25 years)
Average age at MDT screening	27.81 years (SD 9.14; range 15–50, median 27 years)
Timing of limb loss	**Average (SD; range)**
Average interval from GSW to amputation	57.1 days (SD 120.5 days; range 0–547, median 10 days)
Grouped intervals: GSW to amputation	**Patient numbers (*n* = 27)**
Immediate: day 1 amputation	18.5%: 5/27
Within 15 days	37%: 10/27
After 15 days but within 6 months	37%: 10/27
Greater than 6 months	7.5%: 2/27

bone length was 9.35 cm (SD 2.69, range 4–15 cm). Sixty-six percent (18/27) of the stump-plasty cohort was short-stumped (82%: 14/17 of the BKAs and 40%: 4/10 of the AKAs). The majority of BKAs chosen for stump-plasty had deficient bone length before bone revision being commenced.

MDT advised that 41% (11/27) of stumps required revision for bone tip prominence. This would be by bevelling alone in two cases (both BKAs) and bevelling plus shortening in nine cases (six BKAs and three AKAs). Most cases were BKAs (73%, 8/11). Six cases of bevelling and shortening were completed as per the MDT prescription. Two additional BKA stump-plasties underwent shortening and bevelling at surgery without MDT prescription. This increases the current percentage of stump-plasties requiring bone tip revision for bone prominence to 48% (13/27).

Correction of bony prominence decreases tissue tension, allowing advancement of soft tissues. Thirty-three percent (9/27) stump-plasties (30%, 3/10 of AKAs; 35%, 6/17 of BKAs) were prescribed bevelling and shortening primarily to reduce bone prominence but also to mobilise the soft tissues to improve stump tip cover. This was applicable in six BKAs with an average tibial length at 8.7 cm (SD 2.5, range 6–13 cm).

Only three AKA stump-plasties required revisions for bone tip prominence. No AKAs requiring this revision were short-stumped. The bony prominence was related to a tight primary closure technique at amputation. At revision, there was bone spur formation in two AKA cases and an overlong femoral segment in one AKA case (32 cm). For all three AKA cases, correction of femoral bone prominence and soft tissue contour at the tip were revised at stump-plasty.

True bone shortening to reduce bone length was prescribed in 22% (6/27) of stump-plasties. There were two indications: firstly, excessive bone length left at primary amputation in two AKAs (32 and 37 cm) and, secondly, to excise infected bone segments in four BKAs. No BKA stump-plasty case presented with excessive tibial segment length.

Compliance with the original MDT prescription for bone excision in four BKAs with suspected osteomyelitis (OM) (15%, 4/27 stumps) was variable. Patient behaviour, surgical decisions and changes in the course of infection all impacted the final management. Only one patient's care followed the MDT prescription strictly (see SDC 2). Three cases accepted surgery. The fourth case deferred his care due to bereavement. A fifth infective case presented with occult osteomyelitis. Initially prescribed minor bone shortening and bevelling for bone prominence, this patient's X-ray raised the suspicion of OM with all intraoperative bone samples returned with MRSA bacterial growth on culture.

No stump-plasty cases were prescribed true bone shortening for regrowth. Regrowth issues had been addressed prior to the date of the MDT screening clinic. The GMR cohort of 103 amputees had an average age of 26.96 years (SD 9.92, range 13–62 years) at injury. Prior to MDT screening, 23% (24/104) of the mature stumps had already undergone a bone shortening and 46% (11/24) of the cases were for bone regrowth: All regrowth issues occurred in amputees who were under 21 years old at primary amputation.

Change of amputation level was rarely requested from the MDT. Only one amputee was prescribed this management for extensive chronic OM of the femur and tibia with knee ankylosis.

Excision or trimming of the fibular remnant was prescribed for 47% (8/17) of the BKA stumps (30%: 8/27). The indication for removal was most commonly common peroneal nerve (CPN) hypersensitivity (7/8 cases). Only one case was prescribed remnant excision of the fibular bony prominence. Compliance with the MDT fibular prescription was variable for the four BKA stump-plasties completed to date. One case was prescribed total fibular excision and one case fibular trimming. Two other fibular remnants were to be left *in situ*. At surgery, three remnants were totally removed and one trimmed *in situ*. This divergence from the MDT prescription was a preoperative decision by the surgical team on the day of operation. In all four cases, the CPN was cut back as prescribed.

A knee joint contracture was present in 11% (3/27) of those prescribed for stump-plasties. The case requiring alteration of the BKA to an AKA had an irreversible knee ankylosis secondary to infection. Two correctable knee flexion contractures were the result of soft tissue scarring and tethering. Both contractures were released by minor bone shortening and soft tissue redistribution at the stump tip. No muscle release, lengthening or ligamentous procedures were necessary. For both cases, removal of the fibular remnants and CPN trimming were performed at stump-plasty as part of their MDT prescription. One case was short-stumped (8 cm).

Revision, or excision, of the primary amputation scar was prescribed for the majority of stump-plasties (85%, 23/27). Stump soft tissue contour revision was the second commonest soft tissue procedure prescribed (66%, 18/27). This included all AKA stump-plasties (10/10) and 47% (8/17) BKA stump-plasties. This high number of contour revisions reflects that stumps from ballistic injury do not have an ideal form.

Excessive soft tissue, requiring debulking, was present in 26% (7/27) of those who were prescribed stump-plasties. All stumps requiring de-bulking were AKAs (70%, 7/10 of the AKA stump-plasties) reflecting the fatty nature of thigh soft tissue. De-bulking was either by liposuction and soft tissue excision (six cases) or soft tissue excision alone (one case). No cases were prescribed liposuction alone.

Soft tissue enhancement for the paucity of stump tip padding was prescribed in 44% (12/27). This was more frequent in BKAs (8/17) than AKAs (4/10). For the eight BKA cases with soft tissue paucity, the average tibial length was 9.25 cm (SD 2.43, range 6–13 cm). Six of these cases were short-stumped with an average tibial length of 8.17 cm (SD 1.6 cm, range 6–10 cm). Bone shortening was commonly required in order to address the paucity of tip padding. As a consequence, minor bone shortening, concurrent with soft tissue redistribution, was prescribed in 11 of the 12 cases. The nine cases associated with bony prominence have been discussed. For the remaining two cases (one AKA and one BKA), bony prominence was not an issue and bone shortening was solely to allow the scarred and tethered soft tissue to advance, allowing for a tension-free stump closure. In only one of 12 cases (a BKA), was it possible to enhance the paucity of tip cover without shortening the bone.

Myodesis and myoplasty revision were applied to 50% (5/10) of the AKA stump-plasties. In three cases, exploration and revision were indicated for the absence of dynamic muscle sling function. In two other cases, a functional myodesis or myoplasty was opened to gain access to the distal femur for bone revision and then refashioned.

Stump-plasty interventions to address cutaneous issues and foreign bodies were prescribed. Residual split-thickness skin grafts from previous reconstructive efforts presented on the weight-bearing areas 15%: 4/27 of stumps (one AKA and three BKAs). In three cases, soft tissue laxity permitted complete graft excision and direct closure. Soft tissue paucity prevented full excision of unwanted split-thickness skin grafts on one BKA stump. Cutaneous crypts, presenting as invaginated areas of scar tissue and skin prone to maceration, were present on 11% (3/27) of stumps (one AKA and two BKAs). Crypts were addressed by excision and direct closure. Subcutaneous and shrapnel foreign bodies required attention in two BKAs stump-plasties (11%, 2/27). Both presented with palpable foreign bodies, causing localised pain on pressure during socket use. No patient presented with infection around a foreign body. An additional case presented with shrapnel as an incidental finding, intra-operatively, at stump-plasty. All problematic and incidental shrapnel were removed.

Four of the five BKAs (15%, 4/27 stump-plasties) with suspected OM demonstrated cutaneous sinuses at screening. Sinuses were actively discharging from three stumps at screening and one case demonstrated a closed sinus but gave a history of cyclical septic episodes and intermittent discharge. MDT prescribed excision of sinuses and sinus tracts concomitantly with debridement of the bone for OM.

Neural interventions were prescribed at stump-plasty for symptomatic neuromas (33%, 9/27) and CPN hypersensitivity (33%, 9/27). Nine stumps presented with 11 symptomatic neuromas (six BKAs and three AKAs). Two cases had multiple neuromas in a single stump. Table 3 summarises the intraoperative findings of the five stump-plasties performed to date. A total of 16 neuromas were found in five stumps. All seven symptomatic neuromas diagnosed at screening were confirmed intra-operatively. Nine additional asymptomatic, structural neuromas were identified on severed nerve endings. All neuromas were cut back to a zone of soft tissue cover at stump-plasty with no additional manoeuvres.

CPN hypersensitivity was identified in 53% (9/17) of the BKA stumps prescribed stump-plasty. It was of note that 88% (8/9) of the BKAs demonstrating CPN hypersensitivity were also short-stumped. Only one case had a tibial stump greater than 12 cm long. For the nine cases, the average tibial length was 8.56 cm (SD 1.88, range 6–12 cm).

The original MDT prescriptions for CPN hypersensitivity recommended CPN cutback in all nine cases. Concurrent excision or trimming for the fibular remnant was prescribed in seven cases and to be left *in situ* in two cases. To date, four stump-plasties have been completed for CPN hypersensitivity. Although the management of the nerve strictly followed the MDT prescription (all received nerve cutbacks), the management of the fibular remnant varied.

Surgical compliance with MDT prescription was assessed. Sixteen potential orthoplastic orders (SDC 2) could be prescribed by the MDT for the 18 stump-plasty cases completed to date. This generates 288 potential MDT recommendations with which the surgical team could comply with or ignore. Changes to the MDT prescription were rare with 6% (14/228) disparities on the day of surgery. Reasons for noncompliance with MDT orders on the day of surgery included surgical differences of opinion, changes in patients' physical state or changes in patients' decision concerning their surgery.

Preoperative physiotherapy (PT) was only prescribed to 30% (8/27) of the stump-plasty cohort (six amputees for strengthening exercises, one for knee range of motion exercises and one stump for a desensitisation programme). Preoperative PT ceased in three cases due to the stump condition preventing prosthetic fit: Stump discomfort was one factor (two BKAs with CPN hypersensitivity) and stump contour the other (bulbous AKA stump that could not retain a socket). For all three cases, a stump-plasty was necessary before PT could resume. In contrast, all 18 stump-plasty cases engaged immediately with PT postoperatively.

The EQ-5D-5L assessment at MDT screening (Fig. 1) was compared to a repeat assessment 3 months after stump-plasty (Fig. 2). The 18 stump-plasty patients report significant improvement in three out of the five dimensions: usual activities ($p = 0.049$), pain/discomfort ($p = 0.002$) anxiety and depression ($p = 0.04$). The mean VAS scores changed from 58.61 (SD 22.35) pre-stump-plasty to 73.83 (SD 19.44) post-stump-plasty, demonstrating a perceived improvement in the overall health on the day of assessment.

Discussion

Burgess in 1969 described the amputee stump as a dynamic, sensorimotor end organ.[4] The ideal stump has a stable soft tissue cover, is pain free, is of adequate length and has normal sensation. Amputations following ballistic injuries are fashioned in, or close to, the zone of trauma and contain viable but damaged tissues. As such, these amputations can be compared to digital 'terminalisation'.[5] The level of injury and state of tissues in the zone of trauma dictate the level of amputation. This may not be at the level of election on the long bone that a surgeon would have chosen for a standard BKA or AKA. Tissues retained are of variable quality and the definitive stump may fall short of 'ideal'. Stump review and revision may be necessary to maintain a comfortable prosthetic fit with good retention and stability.

This study assesses the mature post-ballistic amputee stump and attempts to rationalise the approach, assessment and surgeries offered to these complex cases. A stump assessment is required at two points in time: (1) early, at first prosthetic fitting and (2) later, at longer-term follow-up for progressive issues

Table 3: Symptomatic neuromas identified at MDT screening in five stump-plasty cases and asymptomatic structural neuromas localised incidentally at surgery in the same patients

Nerve of origin (n = 5 stumps)	*Symptomatic neuromas (clinical trigger points present)*	*Asymptomatic neuroma found intraoperatively (structural, fusiform swelling)*
Femoral	2	0
Posterior cutaneous nerve of thigh	0	1
Tibial	0	4
CPN	1	2
Saphenous	3	1
Sural	1	1
Total	**7**	**9**

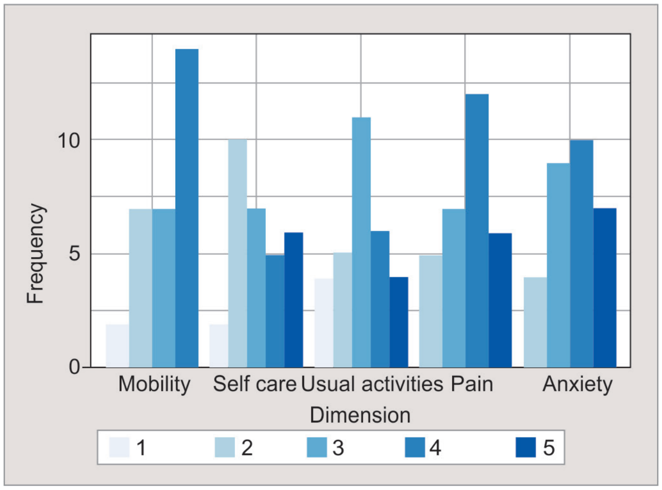

Fig. 1: Preoperative response to the EQ-5D-5L questionnaire at MDT screening for 18 amputees who go onto stump-plasty

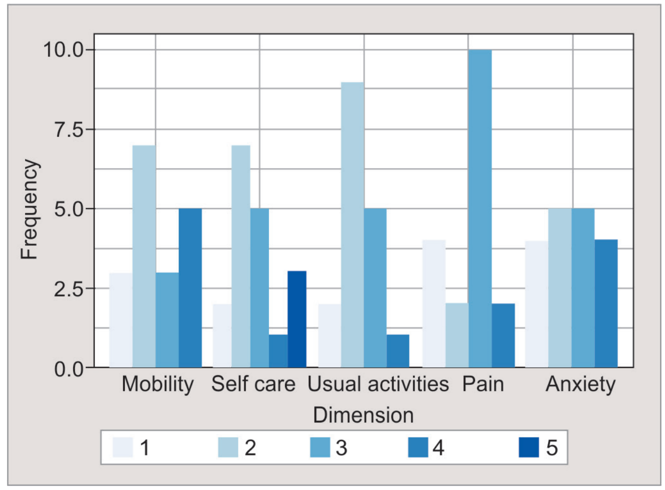

Fig. 2: EQ-5D-5L response of 18 amputees 3 months following stump-plasty. Lower values of severity score are chosen in all five dimensions post-surgery when compared to the scores in Figure 1.

including joint considerations, soft tissue issues, cosmesis and monitoring of the remaining contralateral limb.

We advocate MDT support for these amputees and patient-shared decision-making. The injury affects the whole victim from head to toe, physically and psychologically.[6–8] The Lower Extremity Assessment Project study has already identified how socioeconomic factors, including poverty, can impact negatively the outcome in severe lower limb trauma.[9] Such factors are evident in Gaza but are not a barrier to taking a holistic approach to patient care. A combination of services from prosthetists, physiotherapists, orthoplastic surgeons, psychologists and pain team specialists allows formulation of moderate, measured, patient-centred decisions. Collective decisions made by MDT allow appropriate distribution of resources available to maximise the outcome for each amputee.

Stumps created after surgery from post-ballistic injuries present with varied, yet specific, problems. Individualised care plans, recording issues and specific patient goals, can be formulated. A central concept to our MDT approach was that not all perceived surgical issues necessarily require revision. Assessment and discussion between prosthetists and surgeons identified if the prosthesis design could be altered to 'fit around' an issue. This approach requires MDT follow-up and provision of a workshop for fitting, repair and replacement of the prosthesis. As long as the suitable MDT can be assembled, this approach is possible in lower income countries. There is no saving, either financial or emotional, from incomplete amputee care. The goal is mobility, not the supply of a prosthesis that cannot be worn or maintained.

Stump-plasty is an operation born from necessity in Gaza. This term was chosen to indicate the stump as the structure revised and the change of form after orthoplastic revision. It unifies the multiple procedures possible on each tissue-specific element of amputee stump. The revisions possible are dictated by two factors: (1) the quality of the stump tissue and (2) the distribution and abundance of soft tissue at the level of terminalisation. Transfemoral amputations (AKAs) present more abundant soft tissue than the segment retained in a BKA, hence indications for AKA stump-plasty were inevitably different to those in the BKA.

More BKAs than AKAs were prescribed stump-plasty. This contrasts with the distribution of AKA to BKA in the GMR cohort of 104 stumps where AKAs to BKAs were present in almost equal numbers. The level of primary amputation is dictated by the severity and level of the primary trauma.[9] Tissue damage dictates if the knee joint can be retained; bone length must be sufficient for a lever arm and soft tissue quality adequate. Short BKA stumps are a challenge for prosthetic fitting and a paucity of both bone and soft tissue limits useful options at stump-plasty. The majority of BKAs requiring stump-plasty in this study were short-stumped. The lack of quality soft tissue in these short BKA stumps was the cause of most of their unfavourable symptoms and dictated which tissue components were revised at surgery. Scar revision, contour adjustment and bony prominence revision were all more frequent in BKA stump-plasty than AKA stump-plasty. Bone shortening, although undesirable, had to be applied in some instances to allow redistribution of the limited soft tissues. Neuroma formation was more frequent and likely related to the lack of soft tissue cover of the severed nerve ends. The unstable short fibular remnant caused CPN irritation.

By contrast, the two principal revisions for AKA stump-plasties were de-bulking and contour correction, reflecting the abundant soft tissues in the thigh. De-bulking was indicated for socket fit and prosthesis retention as well as to prevent shear between bone and soft tissue that impacts an amputee's balance and stability. Bone revisions were rare components of AKA stump-plasties.

The frequency of tissue-targeted issues in mature stumps was assessed to consider if action at primary amputation could mitigate these problems. An example would be to excise the fibular remnant at primary amputation in predictably short BKA stumps to avoid later issues of CPN hypersensitivity or fibular bony prominence. Each tissue was considered in turn to reflect on how this might influence future practice.

The bone revision took two forms: minor bone trimming or true shortening. Bevelling involved minor shortening and reshaping the bone tip for excessive prominence. Minor bone shortening was also performed at stump tip revisions where the stump padding needed enhancement: For this group, loss of bone length is an undesirable consequence of a necessary revision. Bone bevelling for prominence was the commonest bony revision prescribed at stump-plasty. Improved tip bevelling at primary amputation is thus indicated.

True bone shortening could be prescribed for one of the three reasons: bone regrowth, infection or excessive residual bone length left at primary amputation. The first two issues are unpredictable complications but the latter is avoidable with preoperative planning. The stump-plasties prescribed included true shortening for both excessive residual bone length and infection but not for bone regrowth. This was surprising in view of the young age of the cohort at primary amputation but this anomaly was clarified by 11% of the GMR cohort of amputees who had already received bone shortening for adolescent regrowth before the screening clinic. This demonstrates the need for follow-up in an adolescent amputee who may present soon after the procedure with bone regrowth.

Delayed presentation of OM, or recurrent OM, will be an on-going risk for amputees who either had delayed debridement and closure of the primary leg wound before amputation, or who had a history of bone infection at any point during amputee care.[1,2] With bone infection confirmed in 19% of cases by bone biopsy at stump-plasty, including one case of quiescent OM,[10,11] recurrent and delayed presentations of complex bone infection can be expected in stumps and will need addressing.

All stump-plasties required incision for access. Consequently, revision of the primary amputation scar was the soft tissue procedure most performed, with the opportunity to enhance scar cosmesis taken where possible. Minor cutaneous revisions included excisions of crypts, removal of symptomatic foreign bodies and excision of the skin graft on weight-bearing surfaces. These issues are minor but impact the comfort and containment of the silicone liner and the prosthesis socket. It is rare for shrapnel, an unavoidable consequence of explosive injuries, to be debrided completely at primary surgery. Retained shrapnel may create recurrent issues as pieces surface or become infected. To mitigate these two problems, removal of as much shrapnel and careful skin closure at primary amputation is needed.

Stump contour correction was the second commonest soft tissue revision. For AKAs, this involved de-bulking tissue excess whereas, for BKAs, this was to improve areas of soft tissue paucity. Liposuction was used as an adjunct to the excision of bulk. More shaping at primary AKA would have mitigated this revision. Contour problems relating to soft tissue paucity in BKAs proved a challenge in short-stumped amputees. The functional benefit of keeping the knee joint for the amputee motivated the MDT to maintain these very short stumps rather than advance the level of amputation to an AKA. With MDT involvement, the prosthetic team was able to fit very short BKA stumps by socket modification (shortest 4 cm). Long-term follow-up with respect to the function and comfort of these very short BKA stumps will demonstrate if this practice is preferable to advancing the level of amputation to above the knee.

One-third of the stump-plasty cohort suffered symptomatic neuroma formation.[8] A gold standard for the prevention and treatment has yet to be established but this cohort of patients could provide a prospective opportunity to find some answers.[12,13] The surgical team must have a strategy of treatment for symptomatic and incidental terminal neuromas found at stump-plasty in addition to adhering to the principles of nerve management at primary amputation. Application of targeted muscle reinnervation[14–16] or regenerative peripheral nerve interface techniques[17] could potentially decrease primary neuroma formation, provide signals for prosthesis control and may decrease phantom pain. In view of the incidence of this problem, this needs careful consideration going forwards to ensure that these young amputees are given the best chance of a pain-free future.

Limitations of this study include shutdown of elective surgery, prosthetic fittings and timely follow-up of the cohort due to the COVID-19 pandemic. The follow-up presented is short and long-term follow-up is required to conclude the impact of suggestions proposed. The stump-plasty cohort is small, hence only trends and observations can be recorded in this article. Statistical comment on the significance of clinical variables has been limited to prevent misleading conclusions in a small group.

Patients expressed enthusiasm at engaging with the MDT and screening attendance levels were high. Stump-plasty surgery was followed by an improved response in the health status questionnaire. By identifying issues presenting in amputees with a post-ballistic stump, appropriate medical care can be organised. Surgeons can mitigate long-term stump issues by changes in practice and innovations at primary amputation. This should decrease the requirement for stump-plasty.

A consequence of this study has been the formation of a national MDT ready to meet amputee challenges of the future. A collective viewpoint with balanced decision-making will produce an appropriate prescription of care for the patient. The aim is to prevent unnecessary surgical interventions and promote the best care.[6] Funding can be channeled to aid young amputees maximize their mobility and participate in sports again. Mentoring programs, psychological support and work programs can be activated with the aim to address all issues holistically.

Conclusion

A rationalised and multidisciplinary team approach to post-ballistic injury amputees in Gaza has been developed and the preliminary results shared. This targeted collaborative management indicates that such pathways offer much to young amputees, irrespective of lower socioeconomic context, and help promote training and maintain the MDT approach. The ultimate goal is to decrease the need for a stump-plasty.

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Supplementary Material

Both the supplementary material (SDC1 and SDC2) are available online on the website of www.stlrjournal.com

Supplementary Digital Content 1 (SDC 1): Appendix of terms, principles and tissue-specific procedures performed at stump-plasty.

Supplementary Digital Content 2 (SDC 2): Summary of the MDT prescriptions for procedures in 27 amputees selected for stump-plasty and compliance with these prescriptions in the 18 cases completed to date.

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