

CLINICAL ARTICLE

An evaluation of firework injuries to the hand – New Year 2007

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Abstract

A growing tradition among the residents of Johannesburg, South Africa, is to light firecrackers to welcome the New Year. Despite legal limitations on the sale of these explosives, firecrackers as well as larger fireworks are freely available in stores and on the streets of Johannesburg.

Over the first few weeks of January 2007, our hand unit treated 34 patients who sustained blast injuries due to firecrackers. The injuries were sustained by patients of all ages. Five children were under 8 years of age, with the peak age group being 20 to 35 years. Only 50% of the injured were employed and 18% were scholars.

The majority of injuries were to the right hand, the dominant hand in most patients. Twenty-four patients injured three or more fingers with some fingers having more than one separate injury. Twenty-one patients ended up with tissue loss of one or more digits.

Thirty patients were debrided and/or repaired within five days of the injury. Three patients did not return for follow-up, two developed localised wound sepsis and required re-debridement, and a further three patients required extended follow-up for dressings. The remainder of the wounds healed uneventfully.

Despite adequate wound healing, the functional loss and side-effects of these injuries are long-lasting or permanent. Social, legal and enforcement solutions are essential for the adequate resolution of this problem.

Introduction

Fireworks are traditionally used by many cultures or groups in celebration. They are designed to produce an audible effect by combustion, deflagration and detonation.¹

They are categorised into different classes depending on the amount of explosive contained in the unit. In the United States, federal law categorises fireworks according to the gunpowder content into classes A and B, with more than 50 mg, and class C having less than 50 mg.² In South Africa, firework use is governed by the Explosives Act 26 of 1956. The act sets regulations for the import,

manufacture, sale and use of fireworks. According to these regulations, packages must contain a warning label.

The peak incidence of fireworks occurs around the New Year period, 4th of July celebrations in the USA and Guy Fawkes night (5 November).²⁻⁴ Interestingly, although fireworks are an integral part of the Diwali celebrations and Chinese New year, there are few reports of increased incidences of injuries during these periods.

Fireworks, and in particular firecrackers, are freely available in Johannesburg, a city that was abuzz with amateur firework displays over the New Year of 2007.

The firework of choice was the firecracker. This is a class C firework of varying size. The firecracker has a variable-length fuse that, when lit, gives off a loud sound.

Fireworks are well known to have an effect on animals. Most of the studies published discuss the effect on dogs. Sudden loud noises such as gunshots, thunderstorms and fireworks may result in behaviour such as hiding, destructiveness and excessive drooling, panting and trembling.⁵

The spectrum of firework injuries that has been reported on includes burns, contusions, lacerations, foreign bodies and amputations. There are even reports of death.¹ The majority of injuries result from personal use of firecrackers, they mostly involve the hands (closely followed by the eyes) and most injuries happen at home.²

All patients admitted to our hospital with hand-related injuries were referred to our hand unit. We reviewed the spectrum of hand injuries caused by fireworks on New Year's Day 2007.

Methods

This is a retrospective analysis of 34 patients with hand injuries due to fireworks treated at our hand unit.

The data were collected from patient files and a questionnaire that was completed in the course of follow-up treatment. Details regarding the injury and surgical procedures were well documented in the patients' files.

The questionnaire included questions on demographic data, the patient's dominant hand and occupation, circumstances of the injury, method of acquiring the firework, associated alcohol use, and type of firework.

Types of firework

The types of firework were divided into firecrackers and other.

The firecracker group was then subdivided into small, medium and large according to *Figure 1*. Patients were asked to identify the firecracker according to a scale photograph of this picture. Small firecrackers included model 440 and 450, medium firecrackers included model 460, 480 and 490, and large firecrackers included number 500 and 510.



Figure 1: Different sized firecrackers

Other fireworks included larger "bombs", "grenades" and rockets.

Management

All patients presenting to our hospital are triaged in the casualty and resuscitation areas. The patients who require surgical management or those with specialised injuries to the hand are referred to the surgical patient intake or the orthopaedic patient intake areas.

Patients with injuries deemed in need of surgical intervention have their wounds irrigated and cleaned, dressed with sterile dressing, and a volar slab is applied. Patients are admitted for review and further surgery by the hand unit. The operation is put on the next available list. The hand unit has daily operating lists.

All patients with firework injuries were prioritised and received surgery as soon as possible in no particular order of priority. All children were put on the first available general anaesthetic list.

The spectrum of firework injuries that has been reported on includes burns, contusions, lacerations, foreign bodies and amputations

All patients were asked about the mechanism of injury. Data on their injuries and management were collected.

Due to the large volume of patients every effort was made to perform definitive surgery at the first operation. This included repair of salvageable tissues and debridement and closure of non-viable areas. Fractures were fixed by means of open reduction and K-wires. Patients who required secondary procedures received them on the same admission.

Surgery was performed by consultants and registrars in the unit.

Patients were then reviewed at our outpatient clinic and followed up as outpatients. Any patient requiring further surgery was readmitted and treated appropriately.

At follow-up, patients who consented to being included in a report were asked to complete a questionnaire on the circumstances of their injury.

Wound follow-up was done at the same time. Wounds were described as clean, sloughy or septic. In patients with multiple wounds, the wound with the worst outcome was recorded.

Patients were referred to our in-house occupational therapists and physiotherapists for rehabilitation. Once all wounds had healed and function was returning, patients were discharged from our care to come back as necessary.

Results were entered into an Excel (Microsoft) spreadsheet and data were analysed for statistical significance.

Results

Three patients did not return for follow-up visits. Their missing data was marked as unknown.

Demographics (*Table I*)

In total, 34 patients with hand injuries were treated at the hand unit. All injuries occurred during a three-day period from 30 December 2006 up to and including 1 January 2007.

The average age was 26 years (range 3-53 years). There were five children under 8 years of age (range 3-8 years).

There were six patients at school, 18 patients who were employed and the remaining 10 were either unemployed or their occupation not known.

Patients were referred to our in-house occupational therapists and physiotherapists for rehabilitation

The right hand was the dominant hand in 30 patients and the dominant hand was injured in 26 (76%) patients.

Table I: Demographic data and time of surgery

Patient	Age	Date of injury	Occupation	Injured hand	Dominant hand	Date of first surgery
1	34	31-Dec-06	unemployed	R	R	02-Jan-07
2	23	31-Dec-06	baker - machinist	R	R	02-Jan-07
3	30	31-Dec-06	floor controller - shop	R	R	03-Jan-07
4	3	31-Dec-06	crèche	R	R	03-Jan-07
5	6	31-Dec-06	grade 3	R	R	03-Jan-07
6	8	01-Jan-07	scholar	R	R	03-Jan-07
7	7	01-Jan-07	grade 3	R	R	03-Jan-07
8	8	31-Dec-07	grade 5	R	R	03-Jan-07
9	34	01-Jan-07	unemployed	R	R	04-Jan-07
10	27	01-Jan-07	painter self-employed	R	R	04-Jan-07
11	42	31-Dec-06	unemployed	L	R	04-Jan-07
12	30	31-Dec-06	mechanic	R	R	04-Jan-07
13	22	31-Dec-07	unemployed	R	R	04-Jan-07
14	19	31-Dec-06	passed matric	L	R	04-Jan-07
15	32	31-Dec-06	lifestyle consultant - gym	R	R	03-Jan-07
16	22	01-Jan-07	customer service representative	R	R	04-Jan-07
17	27	31-Dec-06	security officer	R	R	04-Jan-07
18	19	01-Jan-07		R		04-Jan-04
19	24	01-Jan-07	security officer	L	R	04-Jan-07
20	49	31-Dec-06	machine operator	R	R	04-Jan-07
21	30	31-Dec-06	domestic worker	R	R	04-Jan-07
22		30-Dec-06		L	R	05-Jan-07
23	29	01-Jan-06	mechanic	R	R	05-Jan-07
24	18	31-Dec-06	unemployed	R	R	08-Jan-07
25	26	01-Jan-07		L		05-Jan-07
26	53	31-Dec-07	labourer	L	L	05-Jan-07
27	21	31-Jan-07	unemployed	L	R	05-Jan-07
28	19	31-Dec-06	attending fashion design school	R	L	05-Jan-07
29	34	31-Dec-07	baker	R	R	05-Jan-07
30	34	30-Jan-06	road agency	R	R	11-Jan-07
31	28	30-Dec-06	pikitup cleaner	R	R	12-Jan-07
32*	31	01-Jan-07	call centre employee	R	R	01-Jan-07
33**	40	31-Dec-07	unemployed	R	R	nil
34***		01-Jan-07	logistic company checker	R	R	01-Jan-07

* Initial surgery performed in Margate, KwaZulu-Natal

** No surgery performed – patient presented 2 weeks post-injury

*** Initial surgery performed in Ladysmith, KwaZulu-Natal

Table II: Injury pattern seen

Patient	Thumb	Index finger	Middle finger	Ring finger	Little finger	Palm
1	7 MCP joint	7 MCP	7 mid PP	1	nil	nil
2	1	4	1	nil	nil	foreign body
3	7 mid DP	7 mid DP	7 mid DP	1	nil	1
4	1	7 mid DP	2	nil	nil	nil
5	2	7 mid DP	2	nil	nil	nil
6	7	7 PIPJ	7 mid MP	nil	nil	nil
7	2	2	2,4	nil	nil	nil
8	3,6,8,9, - cmc	7 mid DP, 5 PP	7 mid DP,2	nil	nil	nil
9	4	2	2	nil	nil	nil
10	4	6	2	nil	nil	nil
11	1	6	6	1	nil	nil
12	nil	4	2	nil	nil	nil
13	1	7	4	nil	nil	2
14	2	2	nil	nil	nil	nil
15	6	7	nil	nil	nil	1
16	nil	2	2	2	nil	nil
17	7 DP	7 DP	4	4	nil	nil
18	1	1,6	1	nil	nil	2 - (fws)
19	7 mid DP	6	2	nil	nil	nil
20	4,6 DP	nil	2	nil	nil	nil
21	2,4	2	2,4	nil	nil	2
22	1	7	7	nil	nil	nil
23	7 DP	1	7 MP	1	nil	nil
24	2	2	7 mid DP	nil	nil	nil
25	nil	nil	4	nil	nil	Nil
26	7 mid DP	7 DIPJ	4	nil	nil	Nil
27	4	nil	7 DIPJ	nil	nil	Nil
28	nil	nil	nil	nil	nil	2 - (fws)
29	2,4	2	nil	nil	nil	nil
30	2	2	7 mid DP	nil	nil	nil
31	2	6	nil	nil	nil	nil
32	1	6 DP	4	nil	nil	2 - (2ws)
33	2	2	2	nil	nil	nil
34	4	7 mid DP	4	nil	nil	nil

Key

- 1 – epidermal sloughing/burn
- 2 – laceration epidermis/dermis
- 3 – laceration with tendon injury
- 4 – nail-bed injury
- 5 – closed fracture
- 6 – open fracture
- 7 – degloving (state most prox level)
- 8 – vascular injury
- 9 – nerve injury

DP – distal phalanx
 MP – middle phalanx
 PP – prox phalanx
 fws – first web space
 2ws – second web space
 MCP – metacarpophalangeal joint
 CMC – carpometacarpal joint
 PIPJ – proximal interphalangeal joint
 DIPJ – distal interphalangeal joint

Circumstances around the injury

The circumstances surrounding the injury were divided as follows: cracker was lit in the hand and exploded before it could be thrown – 17 (50%); an unexploded cracker was picked up off the floor – eight (24%), child playing with a cracker resulting in either child or supervising adult being injured – five (15%); events not clear – four (11%).

Sixteen (47%) patients admitted to using alcohol around the time of the injury

Method of acquiring the firework

The fireworks were acquired by the patients in the following manner: bought at a recognised firework store by seven (21%) of patients; bought from a general store/café by eight patients (24%); bought from a hawker by three patients (8%); picked up off the street by two patients (6%); 10 patients (29%) were injured by a firework bought by someone else; and we could not get information from four patients (10%).

Alcohol use

Sixteen (47%) patients admitted to using alcohol around the time of the injury. Of these, eleven admitted to having consumed more than two units of alcohol.

Type of firework

Three patients were unable to confirm the type of firework. Firecrackers composed the largest proportion of fireworks 26/34 – 76%. The firecrackers were then subdivided into small – 11/26 (42%); medium – 13/26 (50%); and large – 2/26 (8%).

The remaining five patients were injured by a variety of larger fireworks or rockets.

Spectrum of injuries (*Table II*)

The spectrum of the injuries sustained was extensive. An attempt was made to group the injuries and to compare like with like. The injury patterns that were recorded included: partial-thickness burns, laceration into the dermis, nail-bed injury/partial amputation of finger tip, closed fractures, open fractures, degloving of the phalanges (most proximal viable level was recorded) and neurovascular injury.

The hand was divided into six regions: each finger was defined as one region and the palm was classified separately. In order to quantify the severity of the injuries we looked at the number of fingers that were injured, the number of injuries, and the tissue loss of the fingers.



Figure 2: Spectrum of injuries: amputation tip of thumb, lacerations and burns IF and degloving distal phalanx MF

There was a median of three injuries per hand (range 1-8) and a median of three regions that were injured (range 1-5). We divided the group into patients who lost tissue from 0, 1, 2 or 3 rays.

Twenty-one patients lost some tissue – the minimum being an amputation through the distal interphalangeal joint.

Four patients lost tissue from 3 rays. There was tissue loss from two fingers in five patients and from one finger in 12 patients. All of these patients had involvement of the thumb, index finger (IF) and/or middle finger (MF).

The breakdown of injuries was as follows: the thumb was injured in 29 patients, index finger: 29 patients, middle finger: 28 patients, ring finger (RF): six patients, little finger (LF): 0 patients and palm: eight patients.

The most common injury patterns seen were degloving injury, nail-bed injury and lacerations (*Figure 2*). All patients sustained some degree of burn injury.

We evaluated the association between alcohol use and severity of the injury as classified by all three methods above. There was no association between alcohol and an increased severity of injury. We also compared the injuries to the different-sized fireworks and again found no significant relation between the size of the firework and the extent of injury.

Management and outcome (*Table III*)

Only five patients received their initial surgery beyond five days post-injury. The acceptability of five days was due to the fact that the majority of injuries happened during the weekend, followed by a Monday that was a public holiday. Despite this, at the two-week wound review, all but six of the wounds were clean and healing uneventfully.

Three patients who sustained burn injuries and abrasions needed ongoing dressings before the wounds eventually healed.

Two patients developed septic wounds. One patient had a small wad of cracker paper that was not removed from her palm. After re-debridement and oral antibiotics she made an uneventful recovery. The other patient developed a septic amputation stump that was treated with oral antibiotics and removal of sutures. No revision was required and he was discharged. He had his initial debridement done at 11 days post-injury due to late presentation.

Selected cases

The most devastating case was a 34-year-old male who had a degloving injury to the thumb, index and middle finger. Debridement of the non-viable tissue left him with a tissue defect to the thenar eminence and the index and middle-finger metacarpophalangeal joint. The bone was debrided until adequate soft-tissue closure could be obtained. He was earmarked for reconstructive surgery but to date has not returned. He was also unreliable in providing details of the type of firework and use of alcohol (*Figure 3*).

Table III: Management of injuries

Patient	Thumb	Index finger	Middle finger	Ring finger	Little finger	Palm
1	10	10	10	1	nil	nil
2	1	4	1	nil	nil	2
3	7 IPJ	7 DIPJ	7 DIPJ	1	nil	1
4	1	7 DIPJ	2	nil	nil	nil
5	2	7 DIPJ	2	nil	nil	nil
6	7 IPJ	7 mid PP	7 PIPJ	nil	nil	nil
7	2	2	2,4	nil	nil	nil
8	5 CMCJ,2	6 PP,7 DIPJ	7 DIPJ,2	nil	nil	nil
9	4	2	2	nil	nil	nil
10	4	7 DIPJ	2	nil	nil	nil
11	1	5 dp,2	7 DIPJ	1	nil	nil
12	nil	4	2	nil	nil	nil
13	1	7 DIPJ	4	nil	nil	2
14	2	2	nil	nil	nil	nil
15	7 IPJ	7 DIPJ	nil	nil	nil	1
16	nil	2	2	2	nil	nil
17	7 DIPJ	7 DIPJ	4	4	nil	nil
18	1	1,7	2	nil	nil	2(fws)
19	7 IPJ	2	2	nil	nil	nil
20	4, 5 DP	nil	2	nil	nil	nil
21	2,4	2	2,4	nil	nil	2
22	1	7 DIPJ	7 DIPJ	nil	nil	nil
23	7 IPJ	1	7 PIPJ	1	nil	nil
24	2	2	7 DIPJ	nil	nil	nil
25	nil	nil	4	nil	nil	nil
26	7 IPJ	7 mid MP	4	nil	nil	nil
27	4	nil	7 mid MP	nil	nil	nil
28	nil	nil	nil	nil	nil	2
29	2,4	2	nil	nil	nil	nil
30	2	2	7 DIPJ	nil	nil	nil
31	1	2	nil	nil	nil	nil
32	1	7 DIPJ	4	nil	nil	2
33	nil	nil	nil	nil	nil	nil
34	4	7 DIPJ	4	nil	nil	nil

Key

- 1 – debridement only
- 2 – debridement and suture
- 3 – tendon repair
- 4 – nail-bed repair
- 5 – K-wire (specify bone)
- 6 – ORIF (specify bone)
- 7 – terminalisation (specify level)
- 8 – vascular repair
- 9 – nerve repair
- 10 – ray amputation

DIPJ – distal interphalangeal joint
 PIPJ – proximal interphalangeal joint
 MCPJ – metacarpophalangeal joint
 CMCJ – carpometacarpal joint
 IPJ – interphalangeal joint
 fws – first web space
 sws – second web space
 DP – distal phalanx
 MP – middle phalanx
 PP – proximal phalanx

The second patient with extensive injury grabbed a medium-sized (490) cracker from his son. He sustained a degloving injury to his thumb, IF and MF and had amputation through the interphalangeal joint (IPJ) of his thumb and distal interphalangeal joint (DIPJ) of the IF and MF. He admitted to alcohol use during the evening (*Figure 4*).

The most common injury patterns seen were degloving injury, nail-bed injury and lacerations. All patients sustained some degree of burn injury



Figure 3: Follow-up loss of radial 3 rays



Figure 4: Grabbed medium-sized firecracker from his son and sustained multiple injuries to each finger and first web space – at two-week follow-up



Figure 5: Eight-year-old boy picked up small firecracker from the floor and sustained tissue loss radial three digits – two-week follow-up

Two 8-year-old children each had tissue loss involving three fingers.

The first child picked up a small cracker (440) from the street and was playing with it. It exploded in his hand and this resulted in amputation of the thumb at the IPJ, index finger midway through the proximal phalanx and through the proximal interphalangeal joint (PIPJ) of the middle finger (Figure 5).

The second 8-year-old picked up a “bomb” that was bought by a neighbour. His thumb was partially amputated through the carpometacarpal (CMC) joint with only the flexor pollicis longus tendon, extensor tendon and a posterior skin bridge intact although the distal soft tissue appeared viable. He also sustained degloving of the tips of the IF and MF. The IF and MF were managed by debridement and terminalisation through the DIPJ. The neurovascular bundle of the thumb was intact but severely contused. We elected to reduce the CMC dislocation and pin it with a K-wire. During relook surgery two days later, the thumb was viable. Follow-up at two weeks revealed a viable, insensate, stiff thumb that was acting as a post. He was sent for rehabilitation (Figure 6).

Two weeks post-injury, one patient presented with poorly-healed lacerations of the thumb, index and middle fingers. She was treated with scar management by our occupational therapists.

No long-term follow-up and functional evaluation was done.

Discussion

Our series of hand injuries is one of the largest recorded by a single institution over such a short period. Other published articles have looked at results and outcomes over many years.^{3,6,7}

Firework injuries have a significant impact on the community. USA population estimates show that approximately 10 000 to 12 600 patients are injured by fireworks every year.^{2,8}



Figure 6: Eight-year-old boy picked up “bomb”, resulting in insensate thumb with CMC dislocation and tissue loss IF and MF – two-week follow-up

Hand injuries account for between 20% and 56% of all firework injuries in large population series.^{1,2,9}

The firework most commonly responsible for personal injury is the firecracker. This accounts for between 30% and 67% of all firework injuries.^{1,2,9} Of our population, 76% were injured by firecrackers. This is higher than the general population because we have selected only those patients who sustained hand injuries. Hand injuries are more commonly seen with the personal use of fireworks, especially firecrackers, while eye injuries and burns are more commonly seen with rockets.²

The majority of our population was in the third and fourth decades of life. More than half of the patients were employed or at school. This accounts for an economically active, educated portion of our community. All of our patients required admission and sick leave, which highlights the economic impact of these injuries.

All injuries reported resulted from failure to heed warning instructions published on the packaging. The warning on the packets include that the user should not

- light the firework in the hand
- pick up unexploded fireworks
- be a child under the age of 16 yrs
- light the firework indoors.

Fifty per cent of our patients were injured by lighting a cracker in the hand, and all commented that the cracker exploded before they could throw it. The manufacturing regulations for crackers state that the fuse should burn for 3 to 5 seconds. This period may, however, prove to be shorter or longer depending on the age of the cracker, how it was transported and the ambient surroundings. A person's perception of time is further more skewed by alcohol and/or drugs.

A prolonged fuse and late detonation are two good reasons why one should not pick up fireworks that have not exploded, yet this was responsible for a quarter of our injuries.

The remaining patients were injured either as a result of children playing with the fireworks or during events that we could not determine.

The association between alcohol use and injury is difficult to quantify. Just under half of the patients admitted to using alcohol and one-third of all the patients had consumed more than the legal limit for driving. The warnings on most firecracker packets include that these should not be used while under the influence.

Hahn *et al* described the spectrum of hand injuries caused by explosives seen by them.¹⁰ They highlight the different mechanisms of injury. These include the pressure effect of the blast, thermal and chemical reactions and debris being driven into the hand.

The extent of the damage depends on three factors: the explosive effect of the exploding object, the medium of transmission and the distance between the exploding and damaged objects.¹⁰ They found six different injury patterns depending on five different hand positions.¹⁰

Our injury profile fits in predominantly with the fireworks being held in prehension or precision grip. Perhaps patients with less damage due to the other positions did not need admission and further surgery or did not present to hospital.

Similarly, we found no direct correlation between the size of the firework and extent of the injury, and no direct correlation with alcohol use and the extent of the injury. This may be attributed to the variable injury pattern produced by the explosion and the circumstances around the injury.

Our role as surgeons is to debride the devitalised tissue and close the wounds in order to minimise septic complications

The devastating effect of the blast resulted in a large number of degloving wounds causing circumferentially devitalised phalangeal bone. The closest ends were often devitalised and needed further debridement. This precluded us from attempting any soft-tissue procedures in order to preserve the length of the digit. The single patient in whom salvage was attempted – the 8-yr-old boy with thumb carpometacarpal (CMC) dislocation – had good collateral blood supply, and no other attempt at revascularisation/re-innervation could be made. Whatever tissue loss is sustained by the blast is the most likely outcome.

Our role as surgeons is to debride the devitalised tissue and close the wounds in order to minimise septic complications. As evidenced by our two-week follow-up data, if a good first procedure is done there is often little need for acute repeat surgery and the sepsis rate is low. Later reconstructive procedures to improve thumb length or close gaps in the rays may be necessary but these can be performed on an elective basis.

Our study is limited in that it is a retrospective review relying on an interview with patients in order to recall the facts. Although the interview was conducted approximately two weeks post-incident, there may be an element of bias in the answers. We are also limited in that we only treated patients requiring referral to a specialised hand unit and this may underestimate the true incidence of injuries sustained. This study does, however, most probably highlight the functionally significant injuries.

The effect of controlling firework injuries by passing laws is generally as effective as the extent to which the laws are enforced. South Africa has laws, and each city has by-laws, controlling the sale and use of fireworks. Different authors have mixed views on the restrictions on the use of fireworks. Some advocate that fireworks be banned,^{5,8} some say that restrictions may not be effective¹¹ but most advocate the safe, restricted and controlled use of fireworks.^{1,7,9}

The spectrum of firework-related injuries is vast. In order to minimise personal injury, however, we recommend that fireworks be enjoyed in controlled environments, that restrictions on their sale and private use be enforced and that the population be educated concerning the risks as well as safe usage.

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• SAOJ

Foot and Ankle Reconstruction fellowship

This is a reminder that I would like to accept a South African applicant to my fellowship programme in the future. I think that the opportunity for advanced training would be quite tremendous, and I am sure that it would be a worthwhile six-month fellowship training.

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Ethical approval

We urge all those who contribute to our Journal to obtain Ethical Approval for their research, prior to undertaking a project for possible publication.

Prof RP Gräbe
Editor-in-Chief, SAOJ