Review of management of traumatic spondylolisthesis of the axis in a Tertiary Academic Hospital

Dr Livinus Obiora Orjiako

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Declaration

I, Dr Livinus Obiora Orjiako declare that this research report is my own, unaided work. It is being submitted for the Degree of Master of Medicine in the branch of Orthopaedic Surgery at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

(Signature of candidate)

12th March 2021 in Johannesburg

Dedication

- This study is dedicated, to the memory of my Late Father, who died one week to the release of my FC Ortho (SA) results
- To my wife and children, for their tremendous support throughout these years

Presentations and publications arising from the research project

None

Abstract

Background: Traumatic spondylolisthesis of the axis (TSA) is the second most common fracture of the axis after Odontoid fracture. The study aims to review the management of TSA patients who presented at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH). Its objectives will be (i) to describe treatment methods used for TSA (ii) to compare the treatments with international best practices (iii) to determine the mechanism of injuries and types of fracture according to Levine and Edward Classification and (iv) to assess radiological outcomes of treatments.

Methods: This was a retrospective study of medical records and radiographs of all patients with TSA who presented to CMJAH from 1st July 2016 to 31st July 2020. All adults 18 years and older with radiological confirmed TSA were included. Patients without follow-up radiological image or lost to follow-up and those with other associated spinal fractures were excluded. We looked at the demographic profile, mechanism of injury, type of fracture, treatment methods and radiological union of the fractures

Results: There were 16 Patients, 75% male and 25% female with average age of 30.5 years were reviewed. There were nine patients (56.2%) with type I fracture, type II, four patients (25%), type IIA three patients (18.8%) and no type III. Motor vehicle accident was the cause in 13 patients (81.2%) and pedestrian vehicle accident in three patients (18.8%). Only two patients with type IIA had operative treatment the rest were treated non-operatively and we had 100% union rate in this study.

Conclusion: There was a 100% union rate and this showed that the majority of TSA fractures do very well non-operatively. Furthermore, the management of TSA fractures at CMJAH is in keeping with the current international best practices.

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Table of contents

List of Figures

List of Tables

Nomenclature

ALL: Anterior longitudinal ligament

ATLS: Advanced Trauma Life Support

C1: First cervical Vertebrae

C2/C3: Second and third cervical vertebrae

CEO: Chief Executive Officer

CMJAH: Charlottes Maxeke Johannesburg Academics Hospital

CT: Computed Tomography

HREC: Human Research Ethics Committee

MRI: Magnetic Resonance Imaging.

PACS: Picture Archiving and Communication System

PLL: Posterior longitudinal ligament

TSA: Traumatic Spondylolisthesis of Axis

MVA: Motor vehicle accident.

PVA: Pedestrian vehicle accident

RTA: Road Traffic Accident

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1 Background

Traumatic Spondylolisthesis of the axis (TSA) is the traumatic anterior subluxation of the 2nd cervical vertebrae (C2) over the 3rd cervical vertebrae (C3), due to traumatic bilateral C2 pars inter-articularis fracture. It is commonly called a Hangman's fracture. Schneider et al. (1), in 1965 coined the term Hangman's Fracture after noting its similarity to injuries sustained in judicial hanging, though it is different from judicial hanging where the spinal cord is usually transected. Nevertheless, the name Hangman's fracture is commonly used for TSA.

It is the second most common fracture of the axis after odontoid fracture. Data from the Swedish National patient Registry stated the incidence of axis fracture was from three per 100,000 to six per 100,000 from 1997 to 2014, respectively. TSA constitutes 25% of those fractures. (2) They are usually stable fractures with neurological fallout only in 5 − 10% of the cases due to auto decompression and increased spinal canal at that level at the time of initial injury

1.1 Mechanism of injury

The mechanism of injury is mainly due to hyperextension and axial compression of the neck. This could be from motor vehicle accidents, diving or fall from height. This leads to stretching of the anterior longitudinal ligament and compression of posteriorly placed bony facets leading to pars fracture and separation of the body from the neural arch. This could extend to posterior longitudinal ligament tear and disc subluxation. (3)

1.2 Literature review

Classification

There are several classification systems such as Josten, Francis etc., but the most widely used is Levine and Edwards modification of the Effendi et al. classification system. This is based on the mechanism of injury and static radiographic images. It is classified into four subgroups (3) namely:

1. **Type I:** vertical C2 pars fracture with no displacement or < 3.5 mm C2 on C3 without angulation.
   The mechanism is axial compression and hyperextension. This is a stable fracture.
2. **Type II:** vertical C2 pars fracture with an anterior translation of > 3.5 mm and > 11 degrees angulation. There is a disruption of the C2 – C3 disc and Posterior longitudinal ligament (PLL). The mechanism is hyperextension, axial load and rebound flexion. This is unstable.
3. **Type IIA:** Oblique pars fracture with significant angulation of greater than 11 degrees and no horizontal displacement. The mechanism is flexion distraction. C2 – C3 disc avulsed and fails in flexion. Anterior Longitudinal Ligament (ALL) left intact. This is unstable fracture
4. **Type III:** Rare type with bilateral dislocation of C2/C3 and pars fracture. The mechanism is flexion-distraction followed by bilateral facet dislocation of C2 on C3 and pars fracture. ALL ligaments and disc are disrupted. Very unstable fractures.

Displacement is defined as the distance between lines parallel to the posterior margin of the bodies of Axis and the C3 vertebra at the level of the disc space between the axis and C3. (4) Angulation is the angle formed from lines drawn parallel to the inferior end-plates of C2 and C3. (4) . A pictorial representation of the fracture types is shown in Figure 1.1.

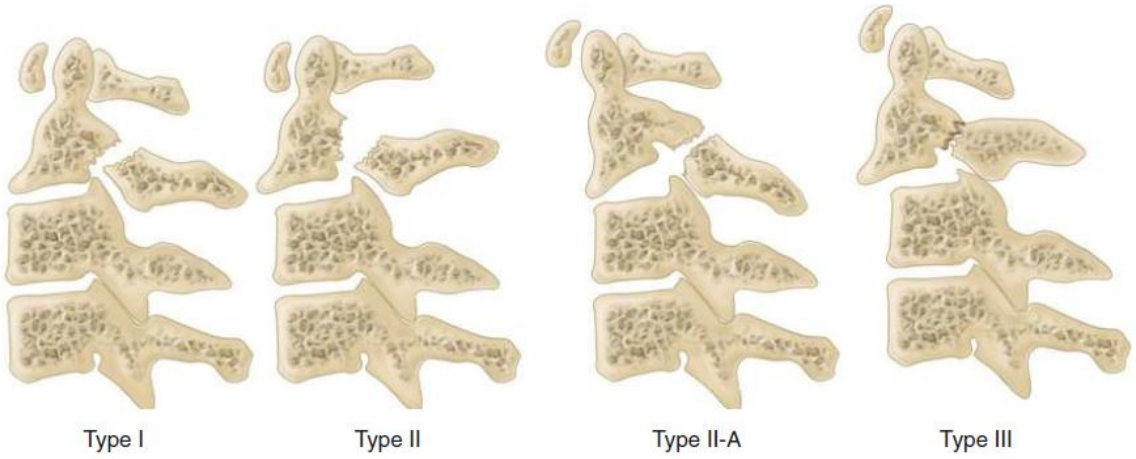

Figure 1.1: Pictoral representation of Levine-Edwards classification of Traumatic Spondylolisthesis of the Axis Fracture. (5)

Not all of Hangman's fractures fall into the above classification and path-anatomy. There are fractures classified as Atypical Hangman. These fractures involve the posterior cortex of C2 on one or both sides or an asymmetrical pattern. These fractures tend to have more neurological fallout because the anterior element does not separate from the posterior elements as in typical Hangman fracture (no auto decompression). (6)

Diagnosis involves history and the mechanism of injury, associated neck pain on examination, neurological assessment and evaluation using advanced trauma life support (ATLS) principle. Radiological images for diagnosis are usually plain radiographs of the cervical spine in anterior-posterior (AP), Lateral (Lat), and open-mouth odontoid views. Computed Tomograhy (CT) scan is the image of choice for fracture delineation. CT angiogram could be done if there is suspicion of vascular injury. A Magnetic Resonance Imaging (MRI) scan is usually utilised for disc and soft tissue evaluation. There is a lack of good evidence to guide the treatment of hangman's fracture and only two prospective studies are available in literature. However, most spine surgeons believe that except for type III TSA, the rest can be treated non-operatively with external immobilisation such as cones callipers traction, halo traction and maintaining reduction with Philadelphia collar or Halo vest. These non-operative approaches have a healing rate of about 95%. (7) Ferro et al. cited facet dislocation and neurological fallout as the only indications for surgical management. (8) Table 1.1 shows the types of TSA injuries, and the appropriate treatments.

Table 1.1: Simplified treatment according to Levine-Edwards Classification (9)

Type I	Hard Neck collar such as Philadelphia neck collar for 6 − 12 weeks
Type II	• If < 5 mm displacement, reduction with Tongs traction for 3 – 4 weeks, then halo or Philadelphia neck collar immobilisation for 6 − 12 weeks • If > 5 mm displacement, prolonged traction, then Halo or Philadelphia neck collar immobilisation
Type IIA	• No Traction in Type IIA. • Reduction with gentle axial load + Neck hyper-extension, then compression halo or Philadelphia neck collar immobilisation for 6 − 12 weeks
Type III	Surgical reduction of facet dislocation followed by instrumented stabilisation required

Coric et al. in a retrospective study on the safety and efficacy of non-rigid immobilisation such as the Philadelphia collar for the treatment of stable hangman's fracture, defined by them as less than 6 mm displacement. They had sixty-four patients managed in one health institution between 1975 − 1994 and thirty-nine had stable fracture and were successfully treated with Philadelphia collar instead of Halo vest for 10 − 14 weeks. (10) Vacarro et al. in a retrospective study in a level I spine unit, evaluated early Halo immobilisation of type II and IIA TSA between 1986 to 1999. They treated twenty seven patients, with twenty one of them having type II and four type IIA. Their conclusion was that Halo immobilisation after traction reduction was an effective method of treatment and greater than twelve degrees initial angulation is associated with a prolonged period of traction. (11)

Li et al. did a systematic review of literature written in English between January 1966 to January 2004 using Medline and Cochrane. Their aim was to determine if there was any scientific evidence to support a standard modality to manage hangman's fracture. They reviewed 32 research studies, 21 of them recommended non-operative management, 11 studies suggested non-operative only for stable fractures. One study suggested surgery as a primary treatment for types II, IIA and III TSA. The limitations were that only studies in the English language were selected and most were retrospective with some having only one patient. Their definition of instability was vague. (12)

Ferro et al. did a retrospective analysis of medical records of 16 TSA patients, treated between 2002 and 2010 in a tertiary academic hospital in Sao Paulo. Five patients were type I, eight patients were type II and three were type IIA, none were type III. All patients were treated with initial traction and subsquently with halo immobilisation. Follow-up was for 9.6 months and all achieved good union. They concluded that non-operative management is satisfactory and safe with very low complications. However, the sample size was small and they had a short follow-up period. (8) Al-Mahfoudh et al. did a retrospective study of 41 TSA patients between 2007 to 2013. Twenty two patients were type I, seven patients type were II and two patients were type IIA. Only three patients were treated surgically, 27 patients with Halo Orthosis and 11 patients with a cervical collar. All achieved clinical and radiological union. They concluded that non-surgical treatment was appropriate for most patients. Therefore, there was no difference between the cervical collar and Halo Immobilisation, thus corroborating Coric et al.'s study. (13)

Murphy et al. did a systematic literature review using PubMed and Scopus for all articles on the treatment of Hangman's fracture with two or more patients in which non-union, treatment failure and complications were compared. Tweny five studies with 548 patients were reviewed, 417 patients had surgery with 99.35% union rate and no increase in mortality as against 131 patients treated non operatively with 94.14% union rate. They concluded that surgery leads to increased bone union without a significant increase in complications. However, this study was limited to studies from 2000 and none of the studies included had an overall low risk of bias. (5)

Solene et al. in a prospective multi-centre observational study between July 2014 to October 2015, under the auspices of the French Society of Spine Surgery, had 34 patients with computed tomography (CT) scan diagnosed TSA. They were followed-up at three and twelve months with repeat CT scan. Twenty one patients comprising 20 patients with type I fractures and one patient with type II were treated non-operatively with rigid braces (16 patients) and Philadelphia collar (three patients). Eleven patients were operated, two patients with type I, eight patients with type II and one with type III. Six patients were lost at one year follow-up, but the remaining 28 patients had good fracture union. They concluded that non-operative management is appropriate for type I, with a 100% union rate and surgery recommended for type II and III with damage to disc and ligaments. However their numbers did not add up in their publication. They said 34 patients were enlisted, but they accounted for only 30 patients treated, they did not account for the remaining four patients. (14)

However, Schleicher et al. in their systematic review of the management of traumatic spondylolisthesis of the axis, could not find high-quality evidence that will guide treatment decisions, because most decisions are based on expert opinion and theoretic considerations. (15) In terms of surgical management, this could be posterior short segment fusion, anterior C2 − C3 interbody fusion, or bilateral C2 pars screw osteosynthesis. Weihu Ma et al. retrospectively reviewed 35 patients with unstable hangman's fractures treated by posterior C2 − C3 fixation. All were observed for an average of 44 months (12 − 78 months). Static and dynamic imaging showed healing occurred in all patients at six months, without any complication. However, this was a level IV evidence study. (16) Patel et al. did a retrospective comparative study of literature comparing the efficacy and clinical-radiological outcomes and complications of anterior fusion/instrumentation versus posterior instrumentation/fusion for TSA. The sample size was 21 patients and time period was 2012 to 2019. There was no difference in clinical-radiological outcomes between the two groups, but the anterior surgery group had shorter surgical time, less blood loss. They concluded that anterior surgery is better. (17) Non-operative treatment is the common mode of management of traumatic spondylolisthesis of the axis with up to 95% healing. Surgery has a role in management but the role has limitations.

1.3 Study Aim and Objectives

The aim of our study was to review the managment of Traumatic Spondylolisthesis of the axis (TSA) patients in a tertiary academic hospital.

The objectives were to:

- To describe treatment methods used for TSA in the spine unit at CMJAH.
- To compare the treatment with international best pratice.
- To determine the mechanism of injuries .
- To determine types of fracture according to Levine and Edwards Classification.
- To assess radiological outcomes of treatments (in this case union)

CHAPTER 2

METHODOLOGY

This chapter describes how the study was designed and carried out.

2.1 Research Question

Is the managment of Traumatic Spondylolisthesis of the axis (TSA) patients at Charlotte Maxeke Academic Hospital (CMJAH) matching with the international standards?

2.2 Research Design

The study was a retrospective study of adult male and female patients from the ages of 18 years and older who presented with Traumatic Spondylolisthesis of the Axis (TSA) at CMJAH.

2.3 Materials and Methods

All patients' clinical notes in hospital record and radiographs in the PACS were reviewed retrospectively.

2.4 Selection Criteria

Inclusion criterion:

- Adult patients 18 years of age and older with radiologically confirmed TSA injury

Exclusion criteria:

- Patients without follow-up radiological images in picture archiving and communication system (PACS)
- Patients lost to follow-up
- TSA injuries with other associated spinal fractures

2.5 Data Collection

Patients' data were collected by the principal investigator (Dr Orjiako), from the patient's hospital files and radiographs from the hospital PACS system. The duration of the study was from 1st July 2016 to 31st July 2020. Human research Ethics clearance was obtained from the Human Research Ethics Committee (HREC), Medical, University of the Witwatersrand (Clearance Number: **M200969**) and permission to conduct the study at CMJAH was granted by the hospital Chief Executive Officer (CEO) (see Appendices A and B). Patients were anonymised by assigning study numbers in order to protect their identities.

The age, sex, mechanism of injury, type of fractures and treatment given were collected from the clinical notes and documented on a data collection sheet (see appendix C). A total of 16 patients were reviewed.

The cervical spine radiographs were reviewed in the PACS. On the lateral views, Displacement is defined as the distance between lines parallel to the posterior margin of the bodies of Axis and the C3 vertebra at the level of the disc space between the axis and C3. Angulation is the angle formed from lines drawn parallel to the inferior end-plates of C2 and C3. (4)

Acceptable union is when three or more cortices are not visible on the AP and Lateral views of the cervical spine radiographs. (4)

2.6 Data Analysis

The raw data collected were entered into Microsoft Excel sheet. Stata 14.0 statistical software package (Stata Corp, Collage Station, TX) was used for data cleaning and analysis. Descriptive statistics were used to describe mechanism of injury, type of fracture, treatment methods and radiological outcomes; frequencies and percentages were reported for these categorical variables. The analysis plan is shown in Table below:

Objective	Data test/tool	Outcome measures
To describe mechanism of injury	Descriptive statistics: • Mechanism of injuries	Frequencies and percentages
To determine the fracture types according to Levine and Edwards classification	Descriptive statistics: • Types of fracture	Frequencies and percentages
To decribe treatment methods used for TSA injuries at CMJAH	Descriptive statistics: • Types of treatment method	Frequencies and percentages
To compare treatment methods at CMJAH with current international best practices	Descriptive statistics: • Cross tabulation	Frequencies and percentages
To describe radiological outcomes of TSA injury treatment	Descriptive statistics: • Radiological outcomes	Frequencies and percentages

CHAPTER 3

RESULTS

3.1 Research Question

Is the managment of Traumatic Spondylolisthesis of the axis (TSA) patients at Charlotte Maxeke Academic Hospital (CMJAH) matching with the international standards?

The STATA version 14.0 statistical package was used for data analysis. Descriptive statistics were used to analyse demographic profile of the participants and fracture characteristics. These were reported as the median and interquartile range for continuous variables, categorical variables were reported as percentages and frequency. Final data analysis was done on a total of 16 patients.

3.1.1: Description of the patients' demographic characteristics

Table 3.1: Patients' demographic characteristics

Factors	**Frequency**	**Percentage (%)**
Age (median = 30.5 years, IQR = 13.0)		
Less than 20 years	1	6.2
20 - 29 years	7	43.8
30 - 39 years	4	25.0
40 - 49 years	3	18.8
50 years and older	1	6.2
Gender		
Female	4	25.0
Male	12	75.0

IQR = interquartile range

3.1.2: Description of the treatment methods at CMJAH

Table 3.2: Treatment methods

Treatment	Frequency	Percentage (%)
Cones callipers for 3 wks and hard neck collar for 8 wks.	5	31.25
Hard neck collar for 10 wks.	9	56.25
Occipito-cervical instrumented fusion	1	6.25
Posterior C1 – C3 spinal instrumented fusion	1	6.25

Table 3.3: Treatment methods compared with type of injury

	Classification of injury			
	I *n*(%)	II *n*(%)	IIA *n*(%)	
Type of treatment				**Total**
Cones Callipers for 3 wks and hard neck collar for 8 wks.	0 (0.0)	1 (100.0)	0 (100.0)	1
Cones callipers for 3 wks and hard neck collar for 8 wks.	0 (0.0)	3 (75.0)	1 (25.0)	4
Hard neck collar for 10 wks.	9 (100.0)	0 (0.0)	0 (0.0)	9
Occipito-cervical instrumented fusion	0 (0.0)	0 (0.0)	1 (100.0)	1
Posterior C1 – C3 spinal instrumented fusion	0 (0.0)	0 (0.0)	1 (100.0)	1
Total	9	4	3	16

Key: wks = weeks

3.1.3: Comparison of the treatment methods at CMJAH with current international best practices

Table 3.4: Treatment methods in CMJAH compared with current international best practices

Type	Treatment	Conform with international standard
1	Hard neck collar for 10 wks.	Yes
1	Hard neck collar for 10 wks.	Yes
1	Hard neck collar for 10 wks.	Yes
1	Hard neck collar for 10 wks.	Yes
1	Hard neck collar for 10 wks.	Yes
1	Hard neck collar for 10 wks.	Yes
1	Hard neck collar for 10 wks.	Yes
1	Hard neck collar for 10 wks.	Yes
1	Hard neck collar for 10 wks.	Yes
11	Cones callipers for 3 wks and hard neck collar for 8 wks.	Yes
11	Callipers for 3 wks and hard neck collar for 8 wks.	Yes
11	Cones callipers for 3 wks and hard neck collar for 8 wks.	Yes
11	Cones callipers for 3 wks and hard neck collar for 8 wks.	Yes
11A	Occipitocervical instrumented fusion	No
11A	Cones callipers for 3 wks and hard neck collar for 8 wks.	Yes
11A	Posterior spinal instrumented fusion	No

Based on the simplified treatment according to Levine-Edwards Classification:

- All of the nine cases of type I fractures were treated in line with current international best practices
- All (four) of the type II fractures were treated in line with current international best practices
- Only one of the three type IIA fractures was treated in line with current international best practices

3.1.4: Determination of mechanism of injury

Table 3.5: Mechanism of injury

Mechanism of injury	Frequency	Percentage (%)
MVA	13	81.2
PVA	3	18.8

3.1.5: Determination of fracture type according to Levine-Edwards Classification

Table 3.6: Fracture Type

Type	Frequency	Percentage (%)
I	9	56.2
II	4	25.0
IIA	3	18.8

3.1.6: Assessment of the radiological outcomes of treatment

Table 3.7: Radiological outcomes of treatment

Radiological union	Frequency	Percentage (%)
Yes	16	100.00
No	0	0.0

CHAPTER 4

DISCUSSION

Under this chapter, the results and findings are analysed and explained in reference to other relevant studies. The peculiar findings of the study are highlighted, and the implications of the overall study are discussed. The limitations of the study are described, and recommendations thereof.

DEMOGRAPHICS OF THE PATIENTS

The demographic characteristics of the patients who presented with Traumatic spondylolisthesis of the axis are discussed below.

Gender of patients

The findings from our study confirmed the fact that TSA injuries occurs predominantly in males. The male to female ratio in this study was 3:1. This male predominance is very similar to the findings of other studies in the literature review (3,8,10) except the study by Rafid Al - Mahfoudh et al. which was 1.3:1 female to male ratio. (13)

Age of patients

The mean age of the 16 patients was 30.5 years. This was slightly lower than the mean age documented in Ferro et al.'s study (39.1 years), Coric et al. study (39.5 years), and Rafid Al-Mahfoudh et al.'s study (59 years). This may be due to the fact that in our study, only one patient was older than 50 years, where as in the other studies they had patients older than 80 years. Our study clearly indicates that TSA injuries occur predominantly among the youth; that is those below the age of 40 years and 75% of the patients in our study were below the age of 40 years.

Mechanism of injury

Road traffic accident (RTA) either as Pedestrian vehicle accident (PVA) or Motor vehicle accidents (MVA) were the only causes of TSA in our study. In other studies, even though road traffic accidents were the predominant cause, there were other causes such as falls and diving injuries (3,8,10), however, in Rafid Al-Mahfoudh et al.'s (13) study, fall was the commonest mechanism of injury (56%) and RTA followed (34%), hence, this might partly explain the higher average age in their study. Motor vehicle accident was the commonest cause of TSA in our study (81.2%), we could not get information on whether most of the patients were drivers or passengers in the vehicles involved. PVA was the second cause of injury (18.8%). This could be explained by the high RTA in South Africa. According to Parkinson et al. (18) in a ten weeks prospective study on burden of road crashes in a regional hospital in South Africa, they found 27.5% road crash related deaths per 100,000 population. Their findings were significantly higher than USA with 10.4/100,000 population. Of the 100 patients admitted in their study 59% where MVA and 41% PVA. Eight percent (80%) of the patients were less than 44 years with 66% males and 34% females. The demographic of their study was similar to our study demographic.

Type of fracture according to Levine and Edward classification

Majority of the TSA in our study were type I (56.2%), type II (25%), type IIA (18.8%) and no type III. This was similar to the findings in the systematic review by Li et al. (12) as well as the studies by Rafid Al-Mahfoudh et al. (13) and Solene Prost et al. (14) However, our findings were not in keeping with Levine et al. (3) and Ferro et al.'s findings. (8)

Treatment and Radiological union outcome

In our study all the nine patients with type I fractures were treated with Philadelphia neck collar for 10 weeks and they all achieved radiological union on final follow-up. This mode of treatment was in line with the treatments in studies by Levine and Edwards (3), Ferro et al. (8), and Rafid Al-Mahfoudh et al. (13) Li et al. (12) in systematic literature review, showed 100 % union rate in all type I TSA treated non-operatively with neck external immobilisation. Coric

et al. (10) and Rafid Al-Mahfoudh et al. (13) in their studies found no difference in fracture union by using Halo immobilisation or Hard Neck Collars such as Philadelphia Collars. All our type II TSA fractures were treated with cones callipers traction for three weeks and definitive treatment with Philadelphia Collars for another eight weeks. All four achieved radiological union at final follow-up. Of the three type IIA, one was treated by reduction in extension and Philadelphia collar for 12 weeks and the patient achieved fracture union.

The two type IIA patients who had posterior open reduction and instrumented fusion/stabilisation were operated by the Neurosurgery team in the absence of the Orthopaedic spine surgeon in charge of the Spine unit at CMJAH. The spine unit at CMJAH only operates unreducible fractures and type III fractures. However, both patients achieved union.

There is paucity of high-quality evidence to guide the treatment of TSA. Schleicher et al. (15) in their systematic review could not find high quality evidence to guide the treatment. However, most spine surgeons and evidence from most studies (3,8,12,11,13) showed that except for type III TSA fractures, other fractures could be treated non-operatively with 95% union rate, using the methods we use at CMJAH. Ferro et al. (8) cited facet dislocation (type III) and neurological fallout as the only indications for surgical treatment. From the available evidence in the literature, our treatment methods are in line with the current international best practices. In addition, our 100% union rate is slightly better than the one reported in literature, which is 95%.

STUDY LIMITATION

The sample size of the study was small (16 patients). However, this is not a common fracture. The study was a single centre retrospective study. Furthermore, the study period was four years, which might be short. Therefore, concrete conclusions cannot be made on the basis of this study.

RECOMMENDATION

We recommend further multi-centre studies (for large patient sample-size) to assess management and outcome of TSA. Furthermore, longer study period can also be looked at to improve the quality of future studies on TSA injuries management.

CHAPTER 5

CONCLUSION

Traumatic spondylolisthesis of the axis (TSA) occurs predominantly in males. It occurs mainly in young patients, especially those below the age of 50 years. These are the productive age group. There is therefore the need to ensure proper treatment. Road Traffic Accidents (RTAs) are the major cause of TSA. Our study confirmed the observation in other studies, that the type I and II TSA injuries treated non-operatively have satisfactory outcomes. Type IIa may require operative treatment, but equally do well non-operatively.

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Appendices

Appendix A: Human Research Ethics Clearance Certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R14/49 Dr Livinus Obiora Orjiako

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M200969

NAME: (Principal Investigator)	Dr Livinus Obiora Orjiako
DEPARTMENT:	Orthopaedic Surgery Charlotte Maxeke Johannesburg Academic Hospital (CMJAH)
PROJECT TITLE:	Review of Management of Traumatic Spondylolisthesis of the axis in a Tertiary Academic Hospital
DATE CONSIDERED:	02/10/2020
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr S.A Khan and Dr M. Jingo
APPROVED BY:	CB Penny Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	05/10/2020

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on the Third Floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions.Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report.** The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed in **September** and will therefore be due in the month of **September** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

7-10-2020
Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix B: CEO permission letter

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

CHARLOTTE MAXEKE JOHANNESBURG ACADEMIC HOSPITAL (CMJAH)
Office of the Clinical Director

Enquiries: Ms. TT Mahlangu
Tel: (011) 488-3365
Email: Thandi.Mahlangu4@gauteng.gov

Physical Address: Room 262A,17 Jubilee, Parktown 2193 Postal Address: Private Bag x39, Johannesburg 2000

23 July 2020

Dear Dr Livinus Obiora Orjiako

STUDY TITTLE: Review of management of traumatic spondylolisthesis of the axis in a tertiary academic hospital

Permission to conduct the above-mentioned study is provisionally approved. Your study can only commence once Ethics approval is obtained. Please forward a copy of your Ethics Clearance Certificate as soon as the study is approved by the Ethics Committee for the CEO's office to grant you the final approval to conduct the study.

Supported/Not Supported

Dr PN Africa
Acting Clinical Director
Date: 23/07/2020

Approved/Not Approved

Ms. G Bogoshi
Chief Executive Officer
Date: 27.07.2020

Appendix C: Data collection sheet

Patient Study number	**Age**	**Sex**	**Mechanism of Injury**	**Fracture type**	**Treatment**	**Radiographic union (Yes or No)**