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FACULTE DE MEDECINE LYON EST

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COMPLICATIONS DES OSTEOSYNTHÈSES PAR PLAQUES SUPÉRIEURES DES FRACTURES FRAICHES DU TIERS MOYEN DE LA CLAVICULE

THESE

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par

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Le Serment d'Hippocrate

Je promets et je jure d'être fidèle aux lois de l'honneur et de la probité dans l'exercice de la Médecine.

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A mon Maitre et Directeur de thèse,
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Je t'aime.

COMPLICATIONS OF SUPERIOR PLATING FOR ACUTE MIDDLE THIRD CLAVICLE FRACTURES

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INTRODUCTION

Clavicle fractures represent a relatively common entity in the field of traumatology. In the adult population, clavicle fractures correspond to 2,6 % to 5 % of all fractures, and in some series, almost half of the scapular girdle fractures.
Middle third fractures are from far the most frequent type of fracture of the clavicle, with a proportion approaching 80%.

The large majority of these middle third fractures occurs in a young and active population, quite often during a sport or work related injury, and are responsible of a variable time of incapacity, frequently of several weeks or months, thus representing a real public health concern.

The treatment of these midshaft clavicle fractures is still not consensual among the orthopedic surgical sphere.

For a long time, these fractures have been neglected and treated with surgical abstinence. This treatment was based of the principle that bone healing was systematically obtained without the need of a surgical procedure.

These last decades, the management of these middle third fractures has been questioned concerning the rates of good results, and a large number of studies have shown a significantly improvement of clinical and radiological results through surgical treatment.

However, there is still nowadays a lack of agreement among surgeons concerning the treatment of middle shaft fractures, especially regarding the choice of a nonoperative treatment versus a surgical approach, and also the choice of the surgical technique in the latter option (plate fixation, intramedullary fixation, or even external fixation).

Surgical plating is one the most frequent type of operative treatment options. The modern plates provide a safe biomechanical fixation of the fracture, as well the possibility to afford an anatomic reconstruction of the bone.

Nonetheless, open fixation using anatomic plates has been decried by a significant part of the surgical community since their emergence, due to supposedly elevated rates of complications, according to these authors.

The goal of this study is to describe precisely the types and rates of complications directly caused by the use of superior plating fixation in the treatment of middle third clavicle fractures in an adult population.

The secondary purpose of this analysis is to see if the main current classification for these fractures (Robinson classification) allows precise description of all the fractures observed in the present series.

FUNDAMENTAL PRINCIPLES AND GENERALITIES

I. DESCRIPTIVE AND FUNCTIONAL ANATOMY OF THE CLAVICLE

A. DESCRIPTIVE ANATOMY

The clavicle is a long-type bone, situated in the ventral part of the scapulo-thoracic girdle, with a quite subcutaneous position.

The clavicle can be separated in three parts : the main body, the medial (sternal) extremity and the lateral (acromial) extremity.

1) THE BODY :

On its a superior surface (**Figure 1**) are located :

- The insertion of the *deltoid muscle* laterally and anteriorly
- The insertion of the *trapezius muscle* laterally and posteriorly
- The insertion of the *sternocleidomastoid muscle* medially

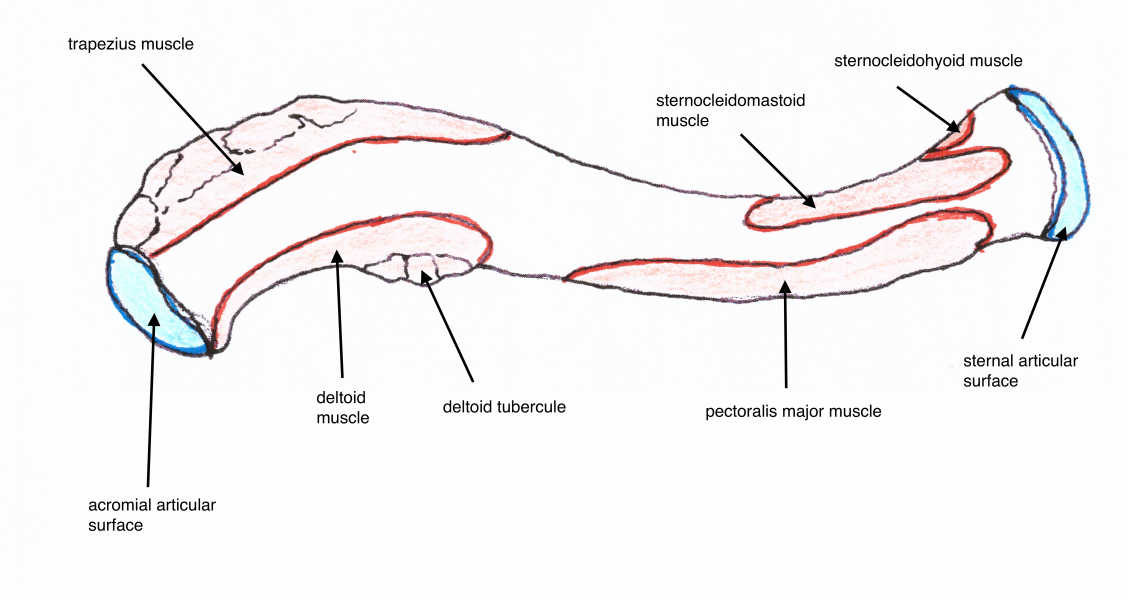

***Figure 1** : Superior view of the clavicle*

On its inferior surface (**Figure 2**) are located :

- The insertion of the *costoclavicular ligament* medially
- The insertion of the *subclavius muscle* in the middle part, in the subclavian groove
- The *conoid tubercule* laterally and posteriorly
- The *trapezoid line* laterally and anteriorly

These last two structures allow the insertion of *conoid and trapezoid ligaments*.

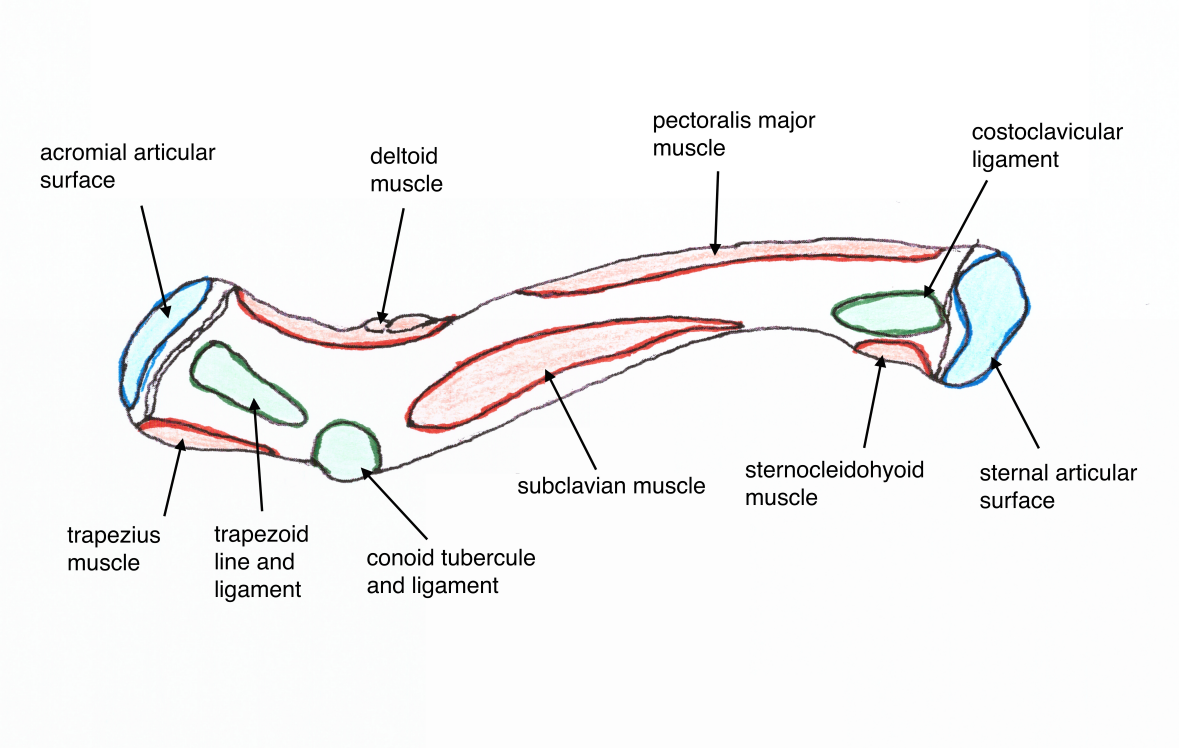

***Figure 2** : Inferior view of the clavicle*

It is important to note that the middle part of the inferior surface anatomically responds to the *subclavian vessels* (vein and artery) as well as the *brachial plexus*. These major structures can be harmed by a bony fragment or even by an exuberant bony callus after healing (**Figure 3**).

Figure 3 *: Anatomic situation of subclavian structures*

On its anterior edge are located :

- The insertion of the *pectoralis major muscle* medially
- The *deltoid tubercule* where the *deltoid muscle* finds its insertion

On its posterior edge are located :

- The insertion of the sternocleidomastoid muscle medially
- The insertion of the trapezius muscle laterally

2) THE MEDIAL END :

It carries on its infero-anterior side the articular surface for the sternoclavicular joint. This articular surface is triangular and convex and responds to the sternal aspect of the sternoclavicular joint as well as the first costal cartilage (**Figure 4**).

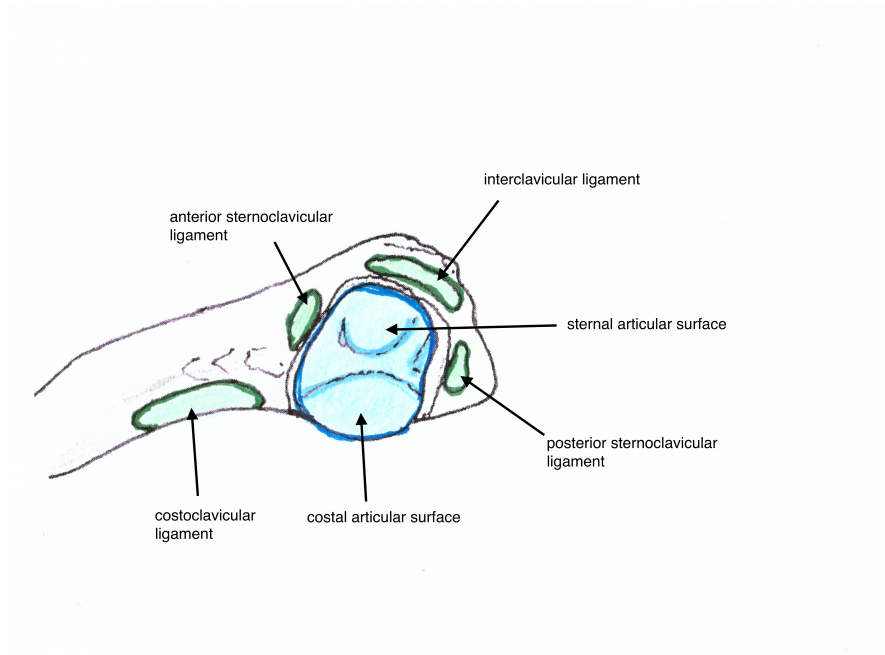

***Figure 4** : Medial extremity of the clavicle*

3) THE LATERAL END :

With a more flattened surface, it responds to the acromion through the articular surface. This oval-shaped articular surface presents a downward and lateral axis (**Figure 5**).

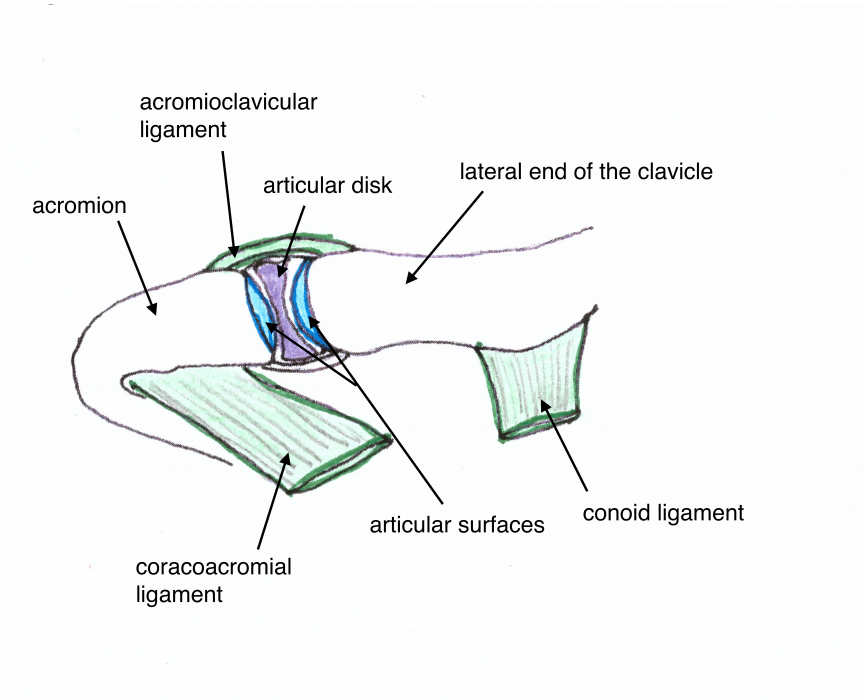

Figure 5 *: Lateral extremity of the clavicle and acromioclavicular joint*

B. FUNCTIONAL ANATOMY AND BIOMECHANICS BASICS

The clavicle is a major element in the function and the stability of the scapular girdle. It functions like a lever arm to help suspend the scapula and thus the humerus, as the rest of the upper limb.

Furthermore, it has been shown that the clavicle, according to studies about evolution and anatomic adaptation among primates and hominids, is associated with animals that carry food to their mouth. Human clavicle presents specific aspects shared by animals that stand erect. [67,68]

The clavicle and the scapula are extremely combined bones. Movements of one induce movements of the other one.
The main source of clavicle movement is the sternoclavicular joint.

RANGE OF MOTION OF THE STERNOCLAVICULAR JOINT :

In the frontal plane :

- 30° of elevation, allowed by trapezius and sternocleidomastoid muscles
- 10° of depression, allowed by deltoid and subclavian muscles

In the axial (horizontal) plane :

- 30° of protraction, allowed by pectoralis major and deltoid muscles
- 10° of retraction, allowed by trapezius et sternocleidomastoid muscles

In the sagittal plane, the clavicle has a very limited rotational range of motion.

The association of these different movements offers the possibility of circumduction. All these movements and ranges of motion are represented in **Figure 6**.

As shown above, the sternoclavicular joint does not allow a large range of motion. However, biomechanical studies of the scapular girdle allowed locating the center of movement of the clavicle in the medial end of the bone, just above the insertion of the costoclavicular ligament (**Figure 6**).

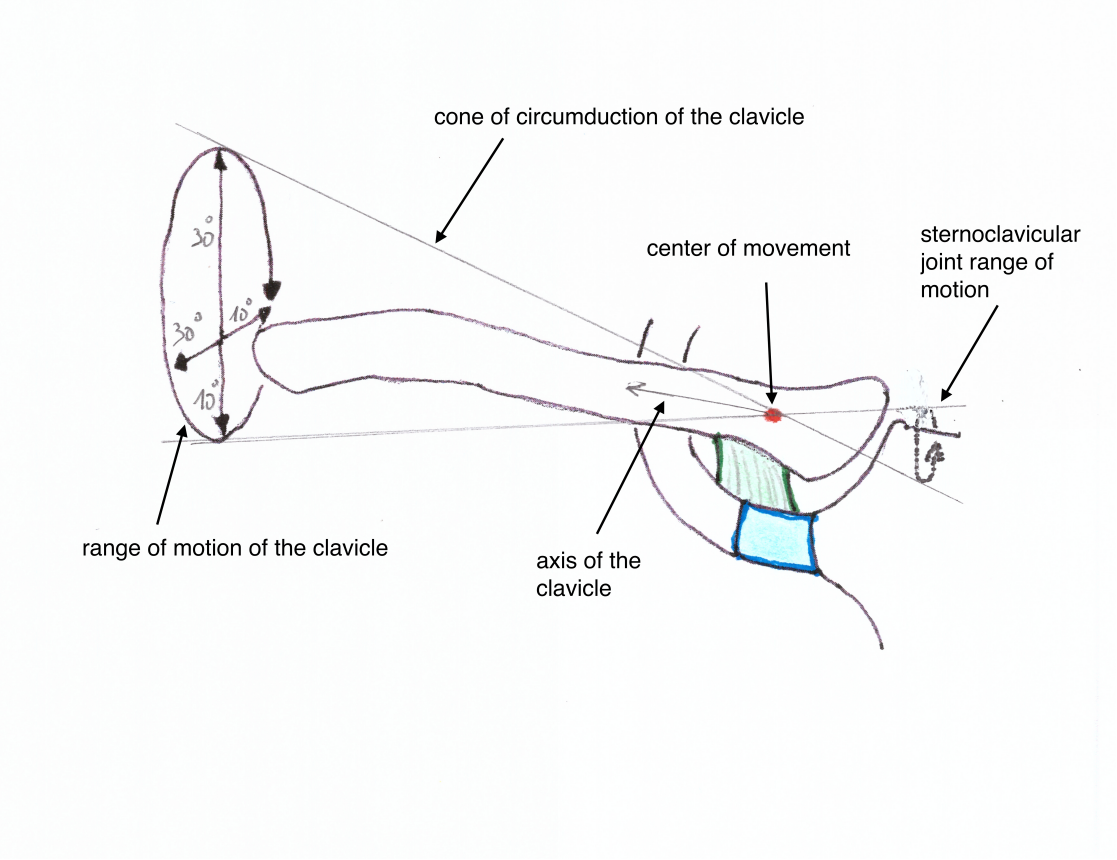

Figure 6 *: Clavicular biomechanics*

This situation, combined with the principle of lever arm that is the clavicle, allows movements of the lateral end simultaneously and in opposite direction, with a far greater amplitude.

While taking into account these elements, it is quite easy to understand the importance of preserving the normal length and axis of the clavicle in order to maintain the function of the scapular girdle.

Regarding the acromioclavicular joint, the range of motion is quite limited and the role of this joint is mainly to absorb the movements of the sternoclavicular joint and transmit these movements to the scapula.

II. MIDDLE THIRD FRACTURES OF THE CLAVICLE

A. EPIDEMIOLOGY

Clavicle fractures are common, represent between 2,6 % and 5 % of all fractures in the adult population. Among the fractures of the scapular girdle, clavicle fractures are extremely frequent, representing 35 to 47 % of these injuries. [31,51,56]
Annual incidence is estimated between 30 and 60 per 100 000 person-years, with a male incidence of 70 per 100 000 and a female incidence of 30 per 100 000. [44,45]

Among these clavicle fractures, middle third fractures are from far the most frequent, representing 69 % to 82 % of all clavicle fractures.
Lateral third fractures proportion is estimated between 17 % and 28 %, and medial third fractures between 2 % to 3 %. [2,31,51,56,63]

Incidence tends to vary according to age of patients. The large majority of middle third clavicle fractures occurs in male patients, aged under 35 years, due to physic activities. A minor recrudescence of clavicle fractures takes place in elderly patients, due to osteoporotic evolution of the bone. [31]

In a large epidemiologic series of 535 clavicles fractures, Postacchini et al. showed that half of middle third fractures were displaced in the general population (including children), and comminuted in 19 % of cases.
Proportion of displaced and comminuted fractures tended to increase with age, with displaced fractures more frequent than non-displaced fractures in the adult population.
This study also showed a slight predominance of left clavicle fracture (61 %).
No seasonal feature was observed. [51]

B. ETIOLOGY AND MECHANISMS

Most of middle third clavicle fractures, while occurring in young and active patients, are due to sport accidents.
In several epidemiologic studies, sport accidents (direct trauma or more often fall on the shoulder) represent the first cause of injury. [31]

Among these sport-related accidents, fall from bicycle or motorcycle are the most frequent. Nowak et al. reported a rate of 45 % of cycling accidents among all causes in women, and 26 % in men. In second position came horse-riding falls. [45]
In Postacchini series, traffic accidents were the first cause of clavicle fractures, but cycling-related falls were still ahead of other etiologies. [51]

Regarding the mechanism of the fracture, direct fall on the shoulder is the more prevalent, with a proportion of 80 % of all mechanisms.
Other mechanisms are : direct impact on the clavicle, fall on the hand while hyperextended, and even seatbelt-related trauma during traffic accidents. [2,31,51,56,63]

C. CLASSIFICATION

While the AO classification is extremely relevant regarding epiphyseal and metaphyseal fractures of the long bones, it is however poorly adequate concerning clavicle fractures, especially middle third ones.

Allman suggested in 1967 a more specific classification, that was quite simple and purely descriptive. [2]

He separated :

- Shaft fractures : Type I
- Lateral end fractures : Type II
- Medial end fractures : Type III

Robinson et al. proposed in 1998 a more precise and relevant new classification of clavicles fracture. [56]
This classification was based on the study of 1000 clavicles fractures treated in the Orthopaedic Trauma Clinic of the Royal Infirmary of Edinburgh, and was developed base on radiological review of the anatomical site and the extent of displacement, comminution and articular extension.

Robinson divided the clavicle fractures as such :

- Type 1 : Medial fractures
    - A : Non displaced
        - A1 : Extra-articular
        - A2 : Intra-articular
    - B : Displaced
        - B1 : Extra-articular
        - B2 : Intra-articular

- **Type 2 : Middle third fractures (Figure 7)**
    - **A : Cortical alignment**
        - **A1 : Undisplaced**
        - **A2 : Angulated**
    - **B : Displaced**
        - **B1 : Simple or wedge comminuted**
        - **B2 : Isolated or comminuted segmental**

- Type 3 : Lateral fractures
    - A : Cortical alignment
        - A1 : Extra-articular
        - A2 : Intra-articular
    - B : Displaced
        - B1 : Extra-articular
        - B2 : Intra-articular

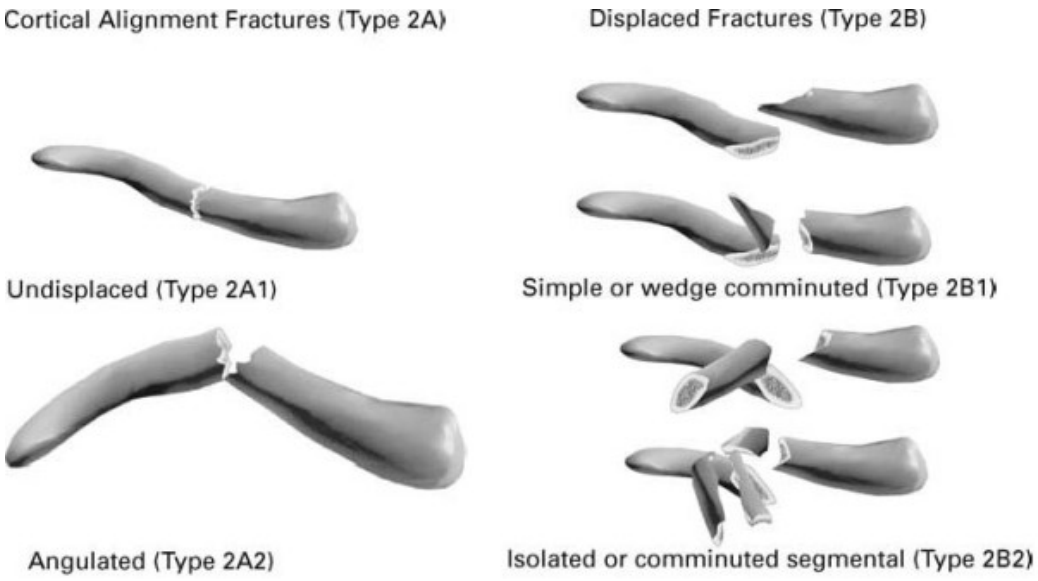

***Figure 7** : Robinson type 2 classification for middle third clavicle fractures*
From Robinson, C. M. “Fractures of the Clavicle in the Adult. Epidemiology and Classification.” *The Journal of Bone and Joint Surgery. British Volume* 80, no. 3 (May 1998): 476–84.

The relevance of this classification lies, in addition to its intra- and interobserver reliability and reproducibility, on its prognostic feature.
Indeed, undisplaced diaphyseal fractures (type 2A1) usually had benign prognosis, whereas incidence of union complications was higher in displaced diaphyseal fractures

(type 2B). Delayed union and nonunion were even higher in comminuted fractures (type 2B2). [31,56]

III. COMPLICATIONS OF MIDDLE THIRD FRACTURES OF THE CLAVICLE

Several types of complications directly related to middle third clavicle fractures have been described, whether acute complications (at the time of the injury) or long-term complications (aftereffects of the fracture on skin, appearance, soft tissues, or shoulder function).

A. ACUTE COMPLICATIONS

1) SKIN COMPLICATIONS

Immediate or secondarily open fractures are relatively rare, with a rate below 2 % in the major studies on the subject.
However, presence of segmental fractured bone fragment with an aggressive subcutaneous situation is not that uncommon, with in some series a rate approaching 30 %.
It is consequently important to not underestimate skin aspects at the initial time of the examination and the treatment. [2,31,59,75]

2) NEUROLOGICAL COMPLICATIONS

Neurological complications of clavicle midshaft fractures directly concern the brachial plexus.
The brachial plexus is intimately related to the clavicle, especially at the middle part, with a mean distance of 15.2 mm. [58]
When a fracture of the midshaft occurs, the lateral fragment is pulled down by the weight of the upper limb, and medially displaced by traction of the muscles (especially the pectoralis major muscle, thus creating the shortening).

This displacement is prone to create a compression or even a laceration of the plexus, resulting in upper limb neurological impairment.
However, brachial plexus lesions related to clavicle fractures are quite rare, occurring in less than 2 % of the midshaft clavicle fractures. [7,58,59,75]

3) VASCULAR COMPLICATIONS

With the same anatomic rationale, caution must be taken when practicing a clinical and radiological examination of a patient presenting a middle third clavicle fracture.
Subclavian vein is the closest structure related to the clavicle cortex, with a mean distance in the medial end of 4.8 mm, slowly increasing while moving laterally. At the junction between medial and middle thirds, mean distance is 6.6 mm. Distance increased to 20.7 mm in the middle part.
Subclavian artery is slightly further located, with a mean distance 18.6 mm at the junction of the medial and middle thirds, and 21.8 mm in the middle part. [58]

Vascular complications rate is estimated around 1 to 3 % of all midshaft clavicle fractures.
Any doubt regarding the possibility of a vascular complication should result in performing a vascular radiological assessment. [2,31,48,59,75]

4) PNEUMOLOGICAL COMPLICATIONS

Occurring of an intra-thoracic complication is also a possibility, especially for high-energy traumatic injuries.
Hemo- and pneumothorax can be related to diaphyseal fractures, and some series report a rate of 3 %. [17,31]

5) FLOATING SHOULDER

The floating shoulder is not per se a complication of midshaft clavicle fractures, but is nonetheless a substantial entity to know and look for when a middle third clavicle fracture is diagnosed.

Floating shoulder is defined by association of a middle third clavicle fracture and a scapula neck fracture. It has also been defined as double disruption of the shoulder suspensory complex (**Figures 8 and 9**).

Such injury is rare but, when diagnosed, surgical treatment has to be at least considered.

Floating shoulder is indeed a potential major unstable injury, especially when ligamentous components of the shoulder suspensory complex (coracoacromial and acromioclavicular ligaments) are divided.

Clavicle fixation often allows stabilization of the shoulder suspensory complex thus avoiding poor functional results. [23,46]

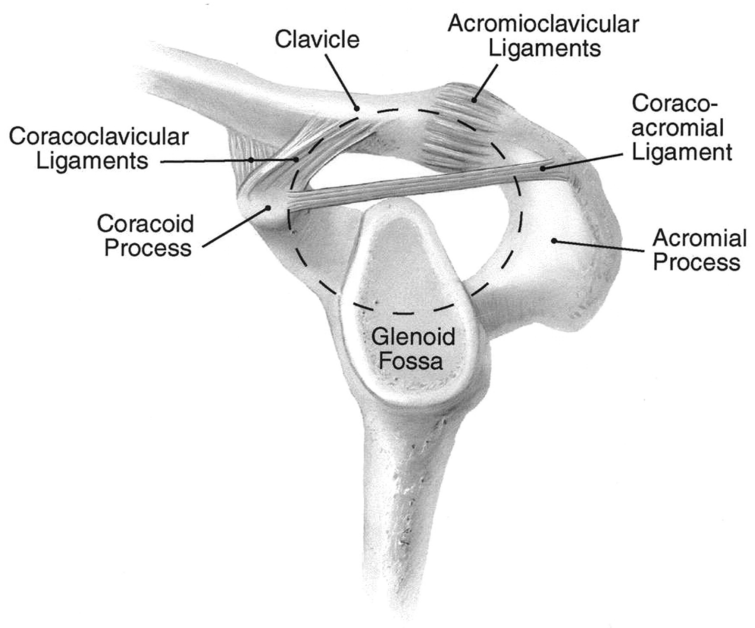

***Figure 8** : Goss' shoulder suspensory complex*
From Goss, T. P. "Double Disruptions of the Superior Shoulder Suspensory Complex." *Journal of Orthopaedic Trauma* 7, no. 2 (1993): 99–106.

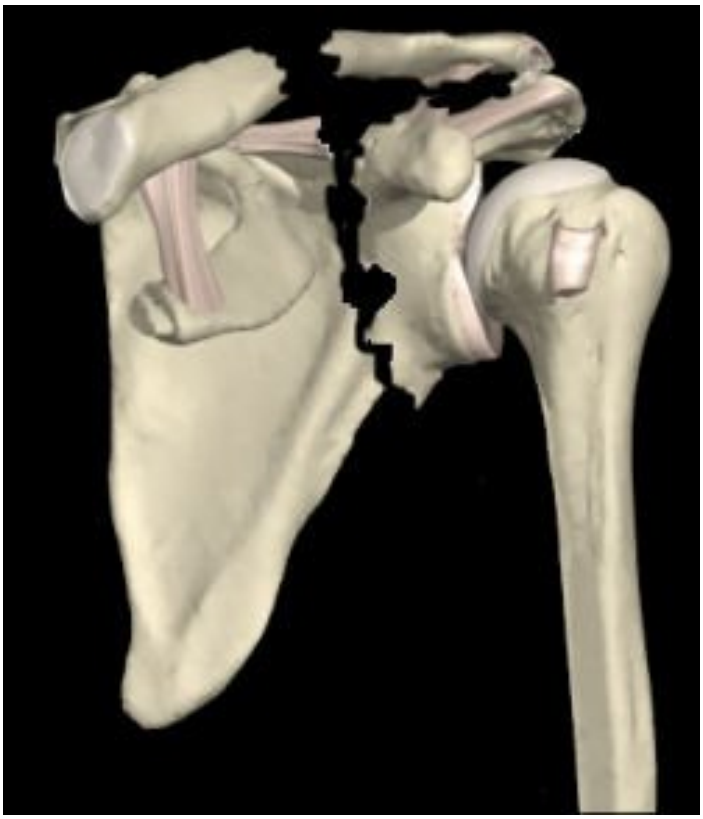

Figure 9 *: Floating shoulder*

B. LONG-TERM COMPLICATIONS

1) NONUNION

For a long time, nonunion of the midshaft clavicle fractures has been considered as rare. Rowe reported in 1968 very low rate of nonunion (less than 1 %). [59,65]
Based on this postulate, surgical treatment has been put aside for decades.
However, recent studies have reported nonunion rates of 5 % to 20 %, making nonunion the major long-term complication of the middle third clavicle fracture. [31,56,57,65]
Nonunion phenomenon has several consequences on the clinical outcome of the clavicle fracture : [31]

- Persistent pain induced by mobility of the fracture
- Interruption of the scapular girdle and of the lever arm role of the clavicle, resulting in a dysfunctional shoulder
- Sport and work disabilities
- Neurovascular irritation in case of hypertrophic nonunion

***Figure 10** : Nonunion of a middle third clavicle fracture*

2) MALUNION

Malunions represents another major complication of displaced diaphyseal fractures of the clavicle.
While frequently asymptomatic, malunions effects can also be source of functional impairment and disabilities, as well as esthetic inconvenience.

Malunions can be divided into two main types : angulated malunion and shortening of the clavicle.

Several biomechanical studies have showed the effect of clavicle shortening, resulting in a complete modification of the scapular girdle anatomy and function, with a loss of shoulder range of motion (especially during elevation and internal rotation), decreased

muscular force, and increased coronal angulation of the clavicle at the sternoclavicular joint. Clavicle malunion is also associated with shoulder girdle pain, fatigue and decreased endurance.

The shortened clavicle medializes the connected acromion and results in scapular winging and three-dimensional deformity (**Figure 11**).

These elements are especially relevant with a shortening of 15 mm or greater. [31,21,28,29,47,65]

Malunion is a further problematic complication on the cosmetic level, when bone healing occurs in an angulated way, thus forming a very noticeable and palpable subcutaneous bony callus, frequently in young and thin patients. [31,21,28,29,47,65]

***Figure 11 A** : Exterior aspect of clavicle malunion (anterior view)*

***Figure 11 B** : Exterior aspect of clavicle malunion (posterior view)*

Alongside with the possibility of neurovascular irritation in hypertrophic nonunion, the brachial plexus or the subclavian vessels can also be compressed by malunion.

IV. TREATMENT OF MIDDLE THIRD CLAVICLE FRACTURES

Treatment of midshaft clavicle fractures has been, and is still a controversial subject. If it is quite agreed that the treatment for non-displaced fractures should be in many cases nonoperative, it is the treatment for displaced fractures that lacks agreement among surgeons.

A. NONOPERATIVE TREATMENT

Nonoperative treatment can be carried either by figure-of-eight bandage or by a simple sling (**Figure 12**).

***Figure 12** : Methods for immobilization in nonoperative treatment*

Although it seems that figure-of-eight bandage possesses the advantage of performing a reduction (at least partial) of the fracture in some cases, some studies showed that they were not significant differences in term of clinical and radiological results. [5,31] Furthermore, nonoperative treatment is not without risk of complications, especially skin lesions reported with figure-of-eight bandage. [5,60]

B. OPERATIVE TREATMENT : CLOSED FIXATION

Closed reduction and fixation can be obtained using either intramedullary hardware or external fixation devices.

1) INTRAMEDULLARY FIXATION

Intramedullary fixation techniques were developed to treat surgically middle third fractures through closed reduction.
According to some authors, closed reduction and intramedullary fixation techniques allow the benefits of surgical fixation of the fracture (thus lowering the risk of nonunion and malunion) and avoiding the risk of complications related to open reduction and plate fixation (infection, nonunion, wound healing problems).
These techniques are performed using different types of hardware, such as : K-wires, Knowles pins, Hagie pins, Rockwood pins, nails (**Figures 13 to 15**).

Figure 13 *: Intramedullary elastic stable fixation using a titanium nail*

Figure 14 *: Intramedullary fixation using Sonoma Crx® nail*

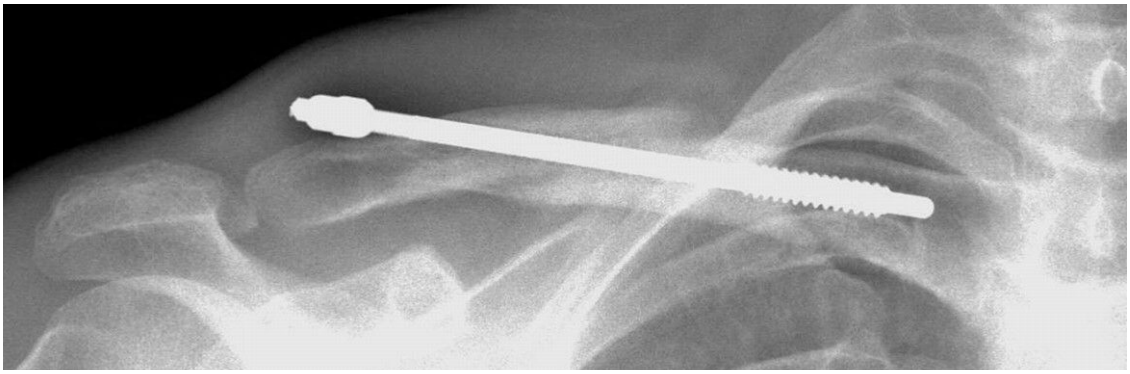

Figure 15 *: Intramedullary fixation using Rockwood pin*

The inconvenient of this technique lies on the fact that hardware used should be thin and flexible enough to go through the medullar canal and follow the clavicle curvature, but strong enough to allow a reliable fixation avoiding nonunion or hardware failure. Furthermore, closed reduction does not allow an anatomical restoration. Intramedullary fixation could eventually be a proper method for simple transverse non-comminuted fractures.

2) EXTERNAL FIXATION

External fixation is not commonly used to treat middle third clavicle fractures, and there is no supporting evidence that it should be considered as a first choice in acute fixation.

C. OPEN REDUCTION AND PLATE FIXATION

Open reduction and plating is the more frequent technique used in surgical treatment of middle third clavicle fractures.
It is the only technique allowing an anatomical reconstruction of the bone, with a stable fixation, thus offering fast pain sedation as well as the possibility of prompt mobilization of the upper limb.

Plating is usually performed through a superior approach, but can also be achieved through an antero-inferior approach. Recent studies showed no significant difference between both techniques. [19,30]

Several types of plates have been developed these past decades. Among the most frequently used are AO reconstruction plates and clavicle anatomic plates, locking or not (**Figure 16**).

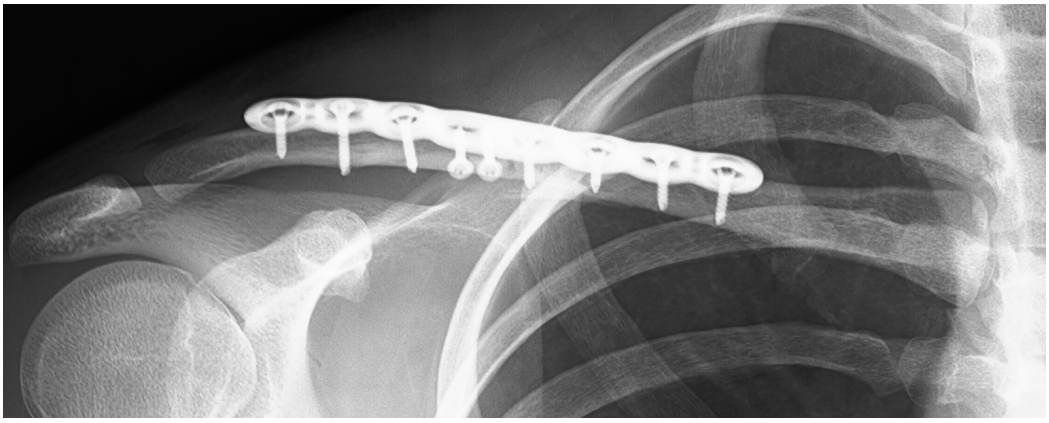

***Figure 16** : Superior plate fixation*

Plate fixation techniques, despite their mechanical and anatomical reliability, are criticized by some authors regarding their supposedly high-rates of complications

(infection, hardware failure, nonunion, wound and scar healing incidents, drilling-related neurovascular damage, and hardware-related discomfort).

This particular point is the purpose of this study.

MATERIALS AND METHODS

I. THE SERIES

A radiological and clinical evaluation of clavicle midshaft plate fixation complications was performed in order to assess the rates and types of each complications directly related to this type of osteosynthesis.

This study was conducted in the Adult Hand and Upper Limb Orthopedic and Traumatology Surgery Department, Edouard Herriot Hospital, Lyon, France.

It consisted in a retrospective consecutive monocentric study.

Between June 2008 and March 2016, 87 patients presenting an acute middle third clavicle fracture were treated surgically by open reduction and superior plate fixation.

These patients either consulted in the Emergency Department or were addressed directly in the Orthopedic and Traumatology surgery Department for surgical consult.

Surgical treatment decision was made after validation by a senior surgeon of the staff.

Surgical procedures were performed by 14 different surgeons.

Inclusion criteria were :

- Surgical plate fixation for acute middle third clavicle fractures

Exclusion criteria were :

- Other type of treatment surgical treatment
- Nonoperative treatment
- History of previous homolateral clavicle fracture
- Surgical plating for nonunion treatment

Clinical and radiological follow-up was performed, and a minimal follow-up length of 3 months was necessary to include the patient.
Patients who did not complete a 3 months follow-up were considered lost to follow-up. Among the 87 patients, one was lost to follow-up data and 3 had not completed the minimal follow-up duration at the time of the survey. The remaining 83 patients completed a minimal follow-up of 3 months.

Complications of superior plate fixation for acute middle third clavicle fractures were consequently assessed based on the data acquired from 83 patients (**Figure 15**)

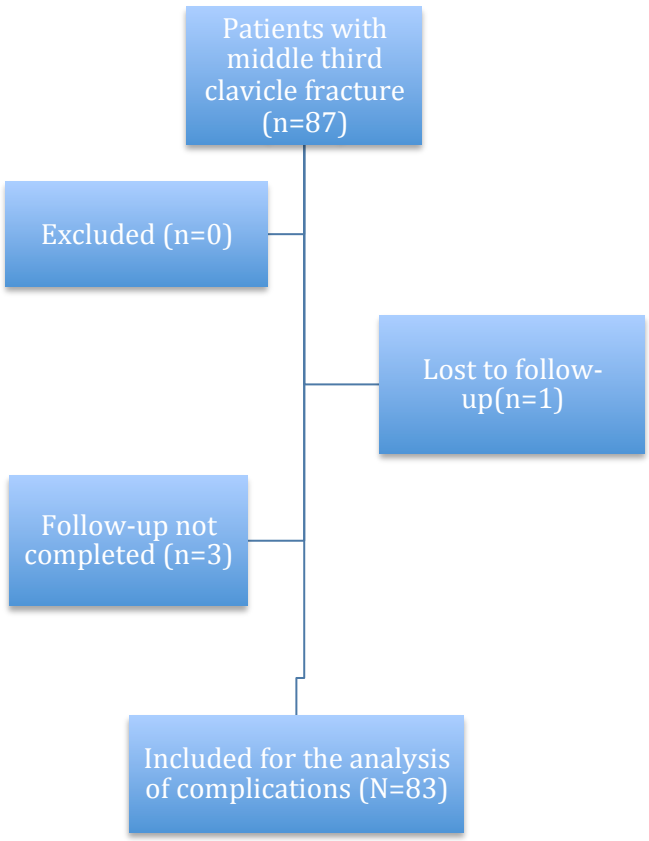

***Figure 17** : Flow-chart of the study*

II. SURGICAL TECHNIQUE

The same surgical technique was performed in every patient, including patient installation, skin incision, and soft tissue dissection.
Four different kinds of plate were used.

A. APPROACH

Procedure is conducted under general anesthesia.

The patient is installed in prone position ; lightly sit up, in the reproducible “beach-chair” position.
Care is taken in controlling every details of the installation, especially anatomic regions were nerve compression or stretching could occur (sciatic nerve, brachial plexus among others).

Meticulous draping allows to expose the whole shoulder area, and it can be interesting in some cases of particularly comminuted fractures, to keep the homolateral iliac crest accessible during the draping, in eventual need of bone grafting.

A superior surgical approach of the clavicle is performed in every patient. Antero-inferior plating was not employed during this study.

Horizontal skin incision is made along the axis of the clavicle.
Subcutaneous and muscle tissues are incised in the same way, straight to the bone.

Care must be taken not to devascularize any bone fragments by leaving muscle pedicles attached to these, thus avoiding increased risk of nonunion.

Reduction is then made possible. Objectives of reduction when using plate fixation osteosynthesis are :

- Maintain of anatomical length of the clavicle
- Maintain of anatomical and mechanical axis of the clavicle
- Anatomical reconstruction of the fractured bone fragments, using if needed interfragmentary screws or osteosuture techniques with large-caliber sutures

B. PLATE FIXATION

Only superior plates were used during this study.
Choice of plate type was made according to the surgeon preferences.

There were no conflict of interest or disclosure regarding the choice and use of surgical hardware used during this study.

Four different types of plate were used :

- Variax Superior Clavicle Locking Plate (Stryker®) (**Figure 18**)

***Figure 18 A** : Variax Superior Clavicle Locking Plate*

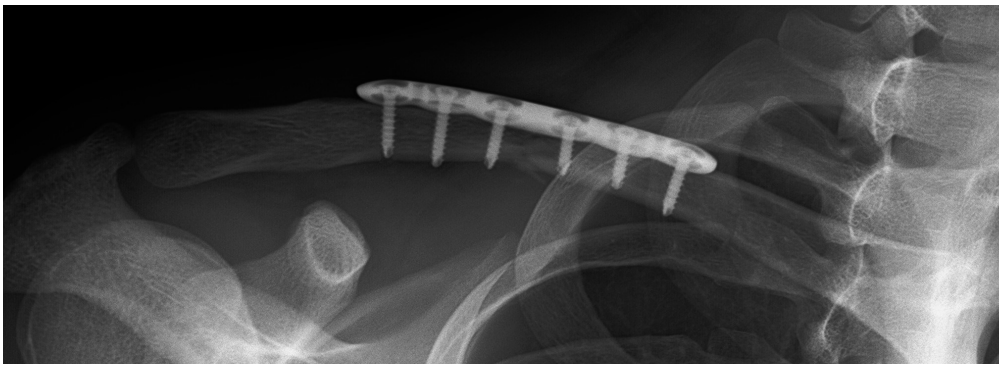

***Figure 18 B** : Variax Superior Clavicle Locking Plate (postoperative x-ray)*

- Variax Lateral Clavicle Locking Plate (Stryker®) (**Figure 19**)

Superior Lateral Plate

***Figure 19 A** : Variax Lateral Clavicle Locking Plate*

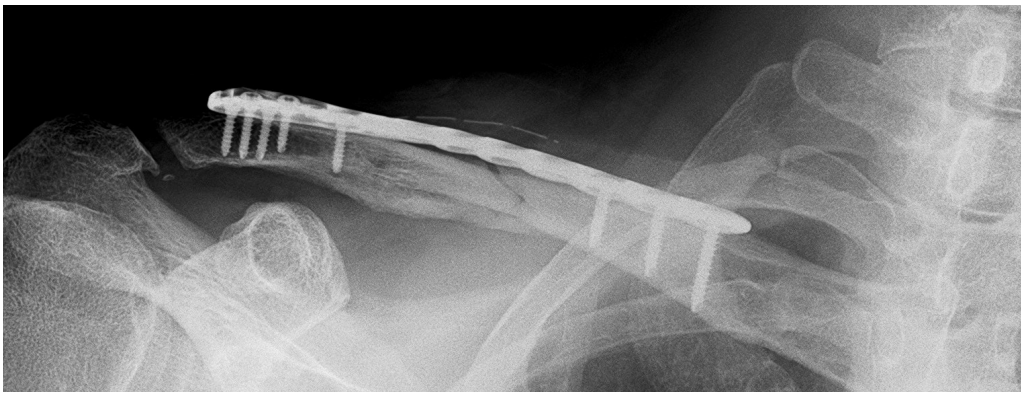

***Figure 19 B** : Variax Lateral Clavicle Locking Plate (postoperative x-ray)*

- LCP Superior Clavicle Plate (Synthes®) (**Figure 20**)

***Figure 20 A** : LCP Superior Clavicle Plate*

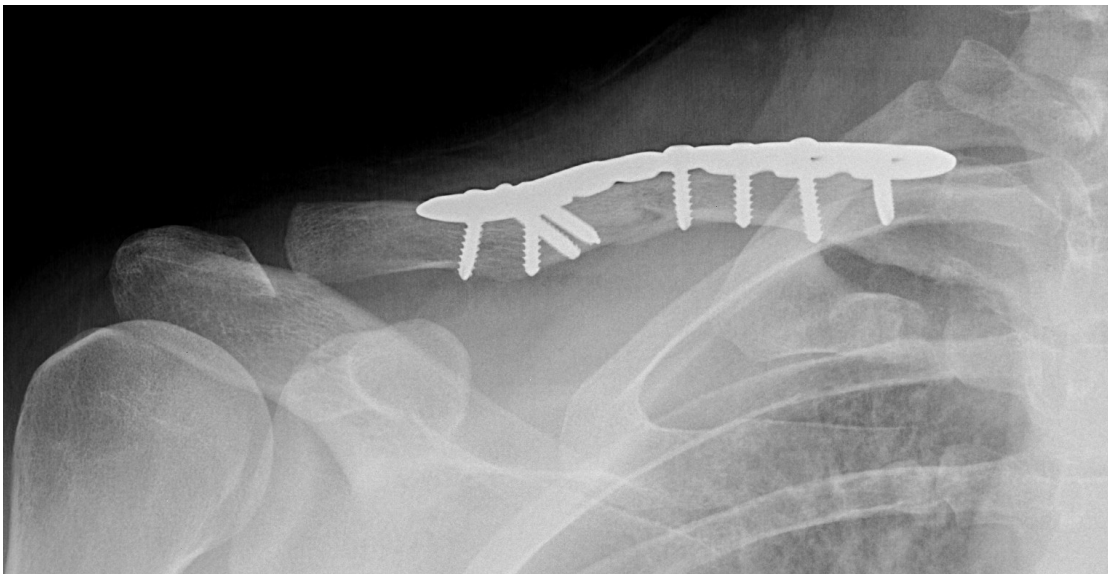

***Figure 20 B** : LCP Superior Clavicle Plate (postoperative x-ray)*

- 3.5 mm Reconstruction Plate (Synthes®) (**Figure 21**)

***Figure 21 A** : 3.5 mm Reconstruction Plate*

***Figure 21 B** : 3.5 mm Reconstruction Plate (postoperative x-ray)*

C. CLOSING AND POSTOPERATIVE CAR

After reliable and stable fixation, soft tissue closing is performed through thorough anatomical sutures, recreating each muscular and subcutaneous anatomical plane. Draining system is left in the operative site according to the surgeon's habits.

Skin closing is achieved with sutures.

A simple sling then temporarily immobilizes the operated shoulder.

III. DATA COLLECTION

For all patients who completed the required follow-up, clinical and radiological data were collected by an independent surgeon.
Pre-operative data were collected about age, gender, side, mechanism, Robinson classification type, initials complications of the fracture, and associated lesions.
Post-operative data were collected about duration of follow-up, type of plate used, and hardware removal.

Primary outcome was global rate of complication.
Secondary outcomes were types and rates of complications and complication-related reoperation rate.

In parallel of this analysis, description of all 87 fractures was done using Robinson classification.
This secondary survey's objective was to see if this classification included every type of fractures observed among the patients of the series.

All radiological analyses were performed using Centricity Enterprise Web 3.0 software.
Data collection was performed using Microsoft® Excel 2011 software.

A. PRE-OPERATIVE DATA

1) PATIENTS CHARACTERISTICS

For each included patient, age, gender and injured side was collected in order to evaluate the homogeneity of the series.

2) ACCIDENT AND MECHANISM

In the same manner, etiology of the fracture was identified for every patient.
Being the main cause of injury in other studies, sport accidents were specifically assessed when responsible of a clavicle fracture.
For every sport-related accident, the type of sport was noted.

In order to assess associated traumatic injuries, likely to occur in case of high-energy accident, presence or absence of other traumatic lesions were recorded.
This collection was made using the principles of accident description of the PAF classification proposed by Pr Herzberg concerning distal radius fractures : [24,25]

- Patients presenting isolated middle third clavicle fracture were identified as mono-injured
- Patients presenting, alongside the clavicle fracture, another osteo-articular injury were identified as poly-injured
- Patients presenting, alongside the clavicle fracture, a vital-prognosis engaging traumatic lesion were identified as poly-trauma patients

3) ROBINSON CLASSIFICATION AND FRACTURE DISPLACEMENT

All fractures were radiologically analyzed before going under surgical plating fixation.
Type of fracture was reported using Robinson classification for middle third clavicle fractures (type 2).
Robinson classification is presented in Part II, Section 2.C (Figure 7).

Displacement of the fracture was analyzed in a two-way feature :

- Presence (1) or absence (0) of a significant shortening (≥ 10 mm)

- Presence (1) or absence (0) of a significant vertical displacement (≥ 100 % of the clavicle height)

4) FRACTURE-RELATED COMPLICATION

Presence (1) or absence (0) of an initial complication due to the fracture itself was marked.
If present, type of complication was specified.

B. POST-OPERATIVE DATA

All postoperative data were collected for every included patient.
Clinical data were collected based on standard postoperative examination, and radiological data were collected from standard clavicle x-rays analysis.

1) FOLLOW-UP DURATION

All patients having completed a minimal follow-up of 3 months, total duration of the follow-up was calculated (in months) for each of them.
Mean follow-up was then reckoned.

2) TIME BEFORE SURGERY

Number of days passed between first consult and surgical procedure was assessed for every patient.

3) TYPE OF PLATE USED FOR THE FIXATION

Of the four types of plates used during this study, specific assessment was made for each patient regarding the plate employed.

4) HARDWARE REMOVAL

Hardware removal procedure was marked absent (0) or present (1) and removal rate was assessed, as well as extension of time between plating and removal.
Hardware removal was not considered a complication itself when requested by the patient and not due to a plating-related complication.

Furthermore, hardware removal-related complications were not assessed as complications of the plating, and were assessed independently.

C. PRIMARY AND SECONDARY OUTCOMES

1) COMPLICATIONS

For every patient, occurring of any complication was marked if present (1) or absent (0). Global rate of complication was then assessed.

Complications were divided into seven categories :

- Hardware failure
- Nonunion
- Malunion
- Infection

- Surgery-related vascular damage
- Surgery-related neurological damage
- Cutaneous and scar dysesthesia

These complications were also specified as major if they carried the patient under reoperation, or minor if not.

1.a) Hardware failure

Hardware failure was marked absent (0) or present (1) if occurring during follow-up. Hardware failure events were not recognized as complications in this study if due to extrinsic factors (for instance, hardware failure due to a new fall days after the surgery). Rate of hardware failure was then estimated.

***Figure 22** : Example of postoperative hardware failure*

1.b) Nonunion

Nonunion is defined by absence of fracture healing after twice the time of normal bone consolidation.

For the clavicle midshaft, nonunion is diagnosed after 4 months without healing following the surgery.
Presence of nonunion after plate fixation was marked present (1) or absent (0). Rate of nonunion was then calculated.

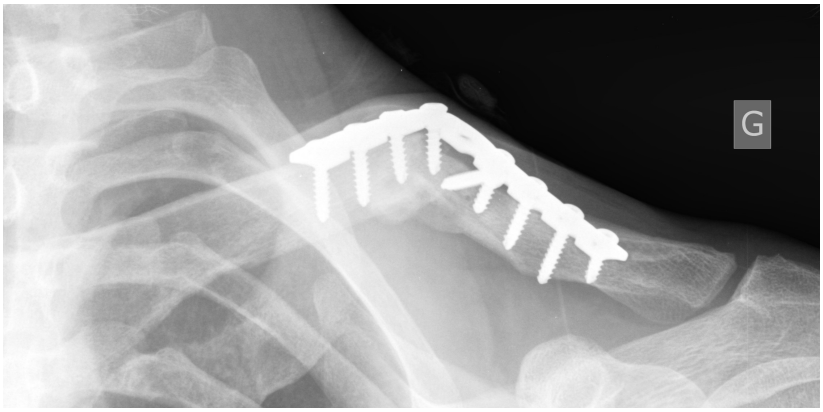

Figure 23 *: Example of fracture nonunion*

1.c) Malunion

Malunion is defined by bone healing occurring in a non-anatomical position, thus being potentially responsible of angulation or shortening regarding the clavicle.
Malunion was marked present (1) or absent (0) for every included patient. Rate of Malunion was then calculated.

Figure 24 *: Example of fracture malunion (angulation)*

1.d) Infection

Infection of the operative site can be superficial or deep.
Superficial infection is defined by occurring within 30 days after the surgical procedure, and is contained to the skin and subcutaneous tissues, above fascial and muscular planes.

Deep infection is defined, in case of hardware positioning, when occurring within the year following the surgical procedure. It can evolve towards a septic osteitis, and requires hardware removal and sustained antibiotic therapy.

Absence (0) or presence (1) of infection during follow-up was assessed.
Occurring infection was specified as deep or superficial, and rate of infection was calculated.

1.e) Surgery-related vascular and/or neurological damage

Risks of surgical plating fixation of middle third clavicle fractures include neurovascular iatrogenic lesions, mainly of the brachial plexus and the subclavian artery and vein, especially during the drilling of the bone.
Such dreadful iatrogenic complications are rare but with major aftermaths, thus requiring protection of subclavian neurovascular structures while performing the drilling.
Absence (0) or presence (1) of iatrogenic vascular and neurological lesions were assessed.

1.f) Cutaneous and scar dysesthesia

Dysesthesia around the scar represents not uncommon complications after open reduction and internal fixation of clavicle fractures.
They usually fade out and disappear within months.

Absence (0) or presence (1) of dysesthesia was also assessed.

2) RATE OF REOPERATION

Rate of reoperation was calculated based on the number of patients who had to go under a second procedure directly related to the occurring of a major complication. Hardware removal procedures requested by the patient were not included in the reoperation rate, for not related to any complication.

3) STATISTICAL CORRELATIONS

Statistical correlations between series pre- and postoperative data and occurring of a complication were calculated for every item, using Pearson correlation test, Fisher exact test and t-test.
Null hypothesis was absence of correlation between series data and occurring of a complication.

Series data searched for correlation were :

- Patient gender
- Age
- Cause of injury
- Mono-injured, poly-injured or poly-trauma status
- Robinson type of fracture
- Presence of an initial complication
- Time before surgery
- Type of plate used

Statistical correlation was estimated by calculating p-value :

- $p \leq 0,01$: very strong presumption against null hypothesis
- $0,01 < p \leq 0,05$: strong presumption against null hypothesis
- $0,05 < p \leq 0,1$: weak presumption against null hypothesis
- $p > 0,1$: no presumption against null hypothesis

Data collection was performed using Microsoft® Excel 2011 software.

Statistical analyses were performed using JMP 9.0 software (SAS Institute Inc., USA).

We report no conflict of interest or any disclosure in this study.

RESULTS

I. SERIES ANALYSIS

A. PATIENTS

1) GENDER

Among the 87 patients of the series, 70 were male patients (80,5 %) and 17 were female patients (19,5 %) (**Figure 25**).

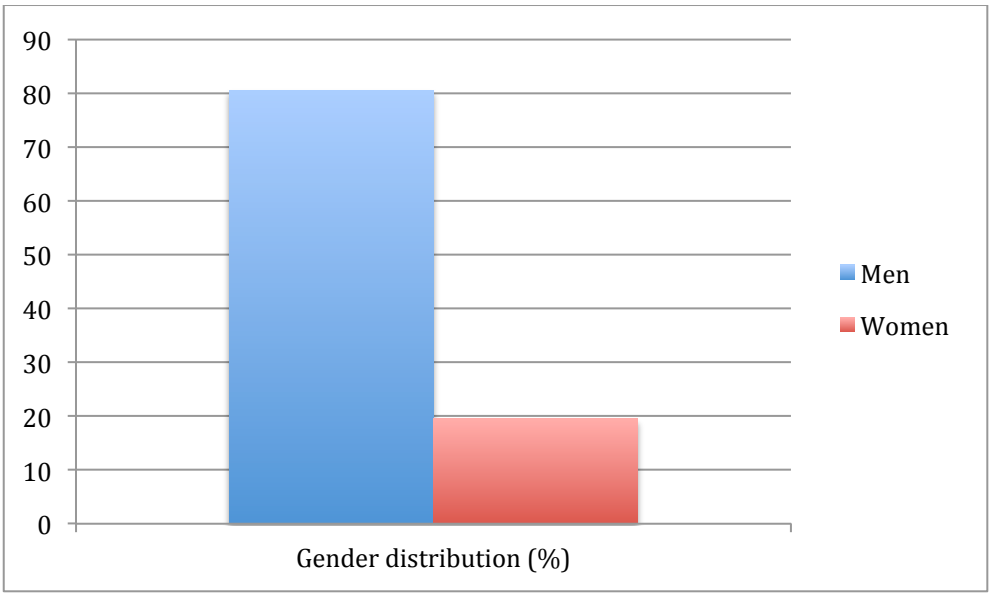

***Figure 25** : Gender distribution of the series*

2) AGE

Mean age of the included patients was 32,9 years, with extreme values of 16 and 73 years.

Mean age of male patients was sensibly higher than female patients' : 34,4 years for man and 27 years for women.

Distribution of fractures by decades showed that 56,3 % (n = 49) of the fractures occurred in patients younger than 30 year-old (**Figure 26**).

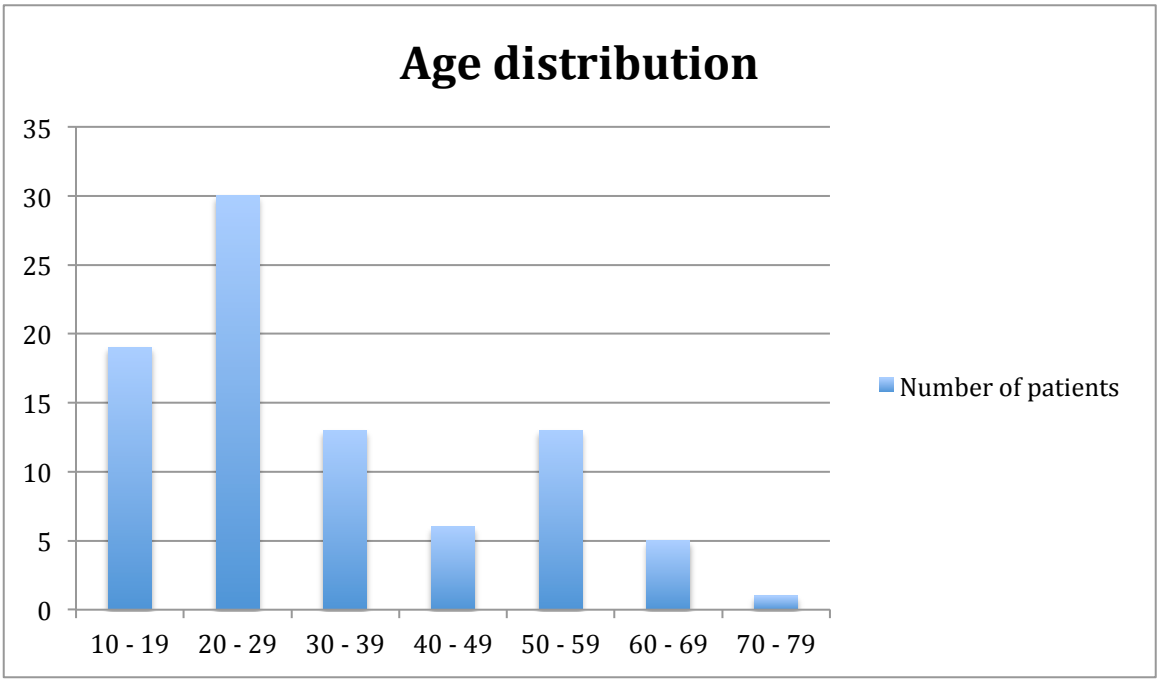

***Figure 26** : Age distribution of the series*

3) INJURED SIDE

Left clavicle was more frequently injured, representing 58,6 % of all fractures (n = 51). Right clavicle was involved in 41,4 % (n = 20) (**Figure 27**).

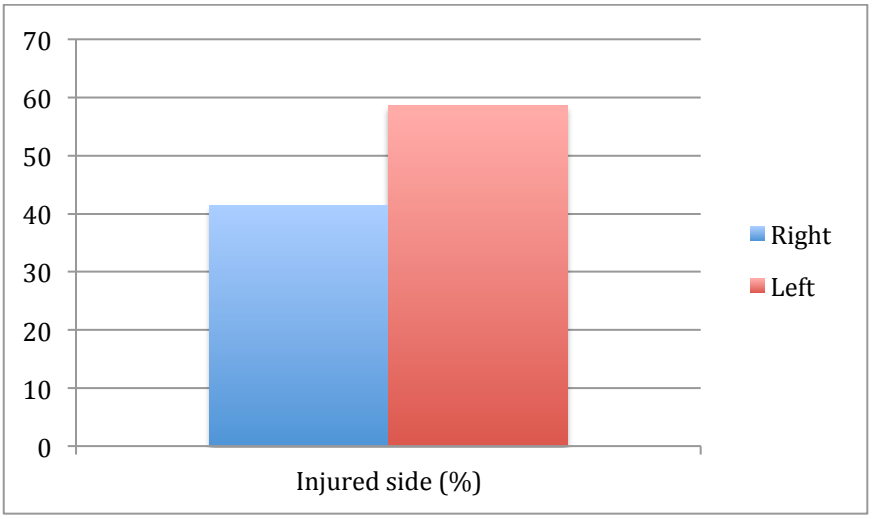

***Figure 27** : Injured side distribution*

B. ACCIDENT

Sport accidents were the most frequent, responsible of the fracture in 46 % of cases (n = 40).
Among sport accidents, leisure bicycling falls were the first cause (16,1 %), ahead of skiing accidents (11,6 %), soccer and rugby accidents (6,9 %), leisure motorcycle falls (3,4 %), horse riding falls (3,4 %), and other type of sport accidents such as running or skateboarding (3,4%).

Behind sport accidents came traffic-road accidents, involved in 37,9 % of fractures (n = 33). Traffic-road accidents involved mostly motorcycles or scooters (23,1 %), bicycles (5,7 %), cars (5,7 %) and pedestrians (3,4 %).

Other accidents (16,1 %) were represented by falls one's full height (12,7 %) and fall from height of 3 m or greater (3,4 %).

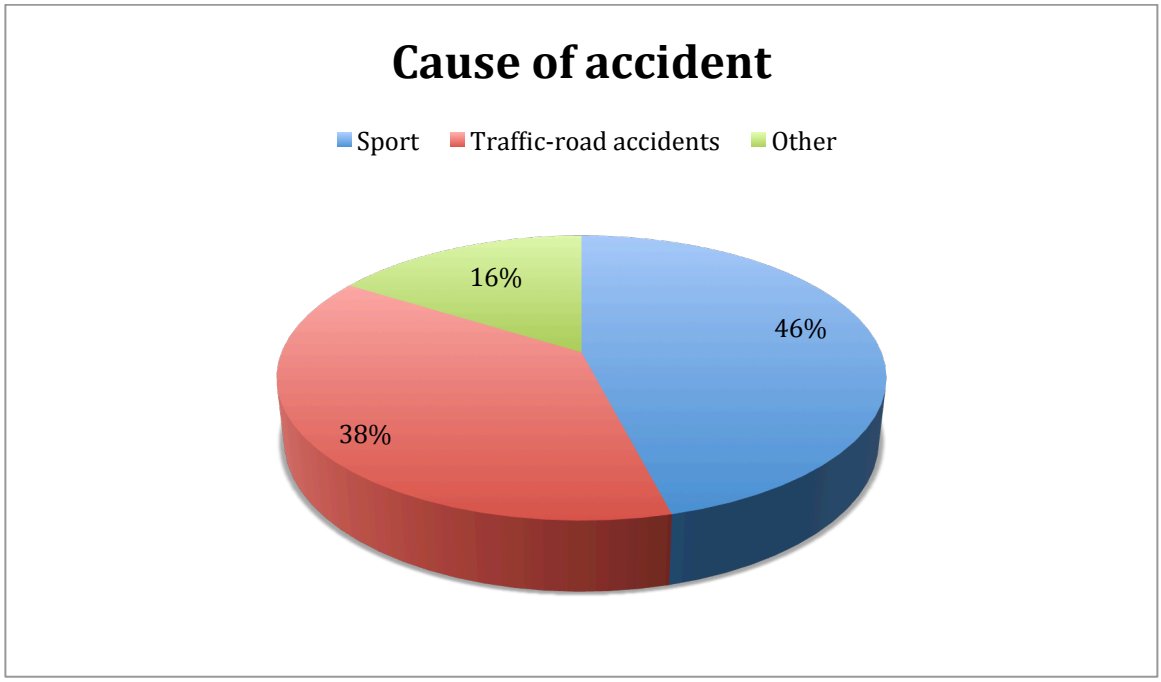

Figure 28 *: Cause of accident distribution*

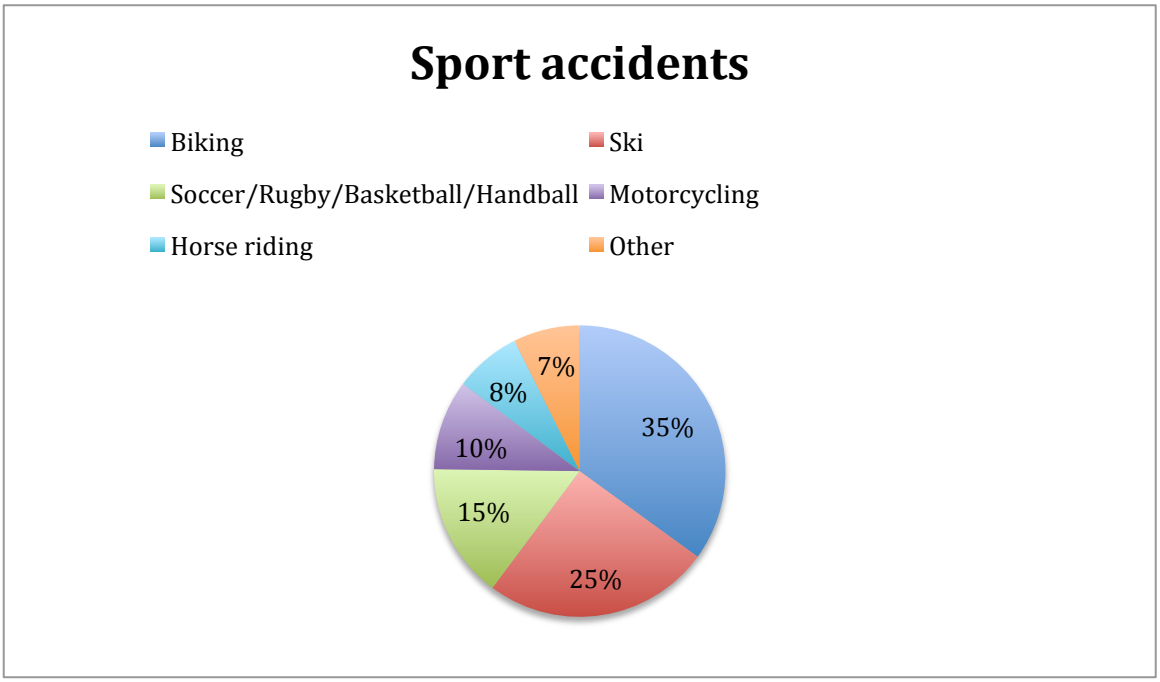

Figure 29 *: Types of sports involved*

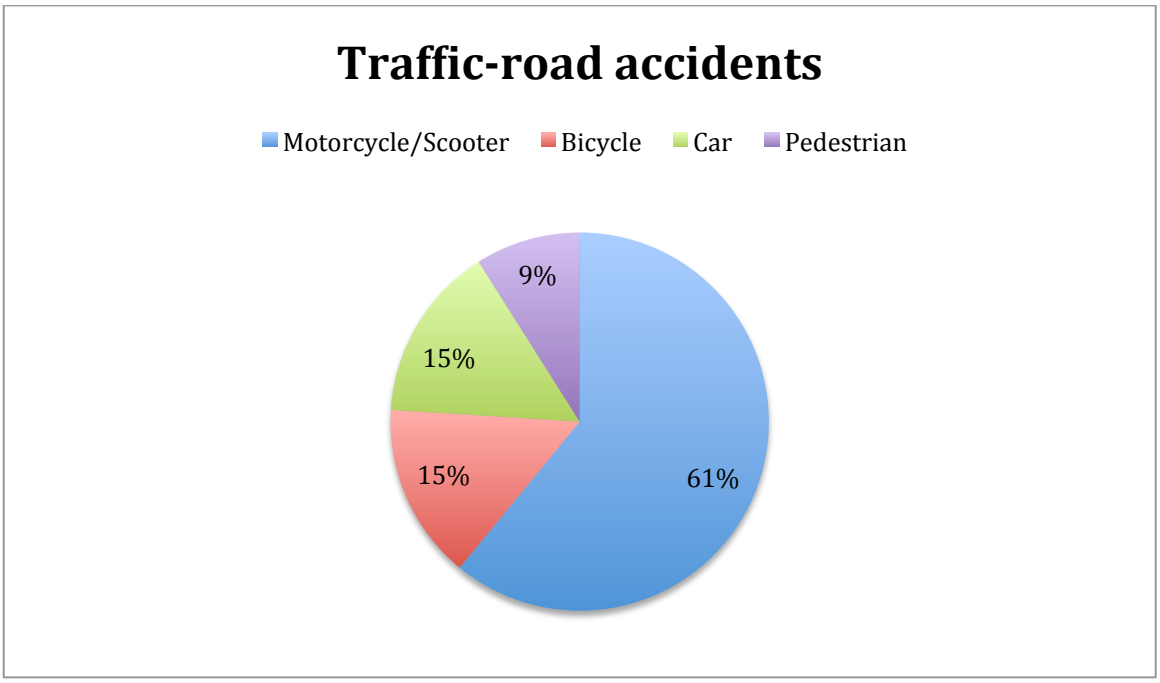

***Figure 30** : Types of traffic-road accidents involved*

Among all causes, falls or accidents involved two-wheels vehicles (bicycle, motorcycle, or scooter), whether for leisure or transportation, accounted for 49,4 % of all injuries (n = 43).

There were 58 mono-injured patients (66,7 %), 18 poly-injured patients (20,7 %), and 11 poly-trauma patients (12,6 %).

C. FRACTURE

1) ROBINSON TYPE OF FRACTURE AND DISPLACEMENT

Following Robinson's classification, there were no 2A types (with cortical alignment).

All patients presented displaced fractures, among which 79 could be identified as 2B types.

Among these fractures, 52 (59,8 %) were 2B1 types (simple or wedge comminuted fractures, **Figure 32**), and 27 (31 %) were 2B2 types (isolated or comminuted segmental fractures, **Figure 33**).

Eight fractures (9,2 %) were not includable in Robinson classification due to their anatomic location (in the lateral part of the middle third), as shown in **Figure 34**.

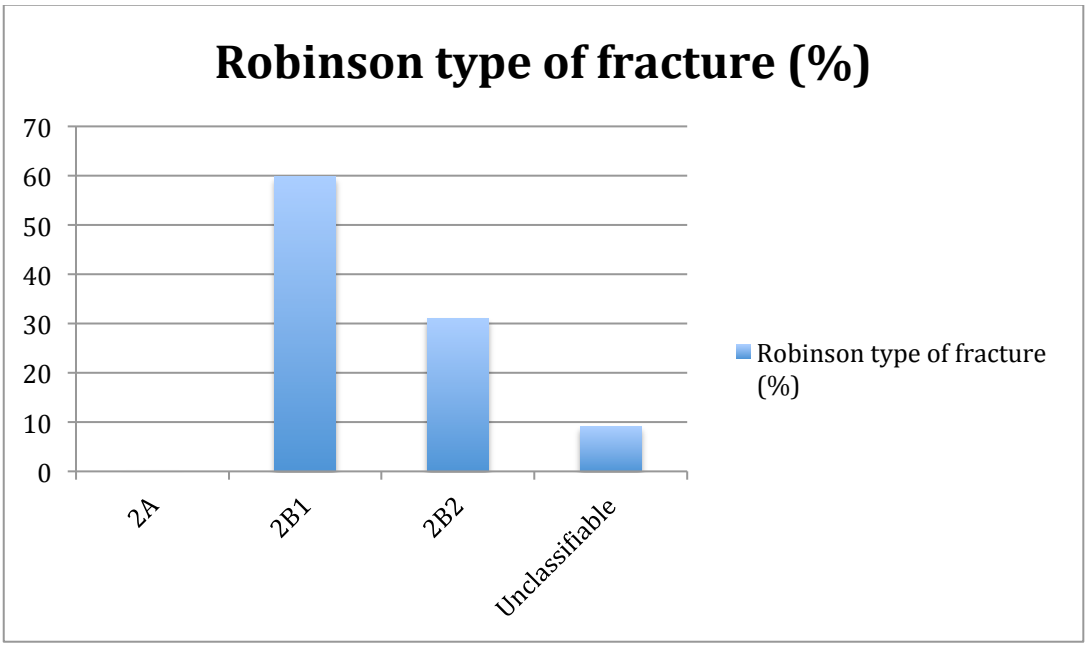

***Figure 31** : Fracture type distribution*

***Figure 32** : Example of 2B1 type fracture*

Figure 33 *: Example of 2B1 type fracture*

Figure 34 *: Example of lateral-middle third fracture*

All fractures were significantly displaced :

- 100 % (n= 87) had a significant vertical displacement (≥ 100 % of the clavicle height)
- 86,2 % (n= 75) had a significant shortening (≥ 10 mm)
- 86,2 % of the fractures presented both criteria

2) INITIAL FRACTURE-RELATED COMPLICATION

Seven patients presented an initial fracture-related complication (8 %).
Among these 7 patients, 5 patients had skin-threatening displacement (5,7 %) and 2 patients (2,3 %) had an open fracture (Stage I of Gustilo classification).
There was no other type of initial complication.

One patient presented a floating shoulder injury, and was treated with exclusive clavicular fixation and nonoperative management of the scapula fracture.

II. TREATMENT

A. TIME BEFORE SURGERY

Mean time before surgery was 7,9 days, with extreme values of 0 and 42 days.

B. TYPE OF PLATE USED

Among the four different types of plates used :

- Variax Superior Clavicle Locking Plate (Stryker®) was used in 29 patients (33,3 %)
- Variax Lateral Clavicle Locking Plate (Stryker®) was used in 10 patients (11,5 %)
- LCP Superior Clavicle Plate (Synthes®) was used in 32 patients (36,8 %)
- 3.5 mm Reconstruction Plate (Synthes®) was used in 16 patients (18,4 %)

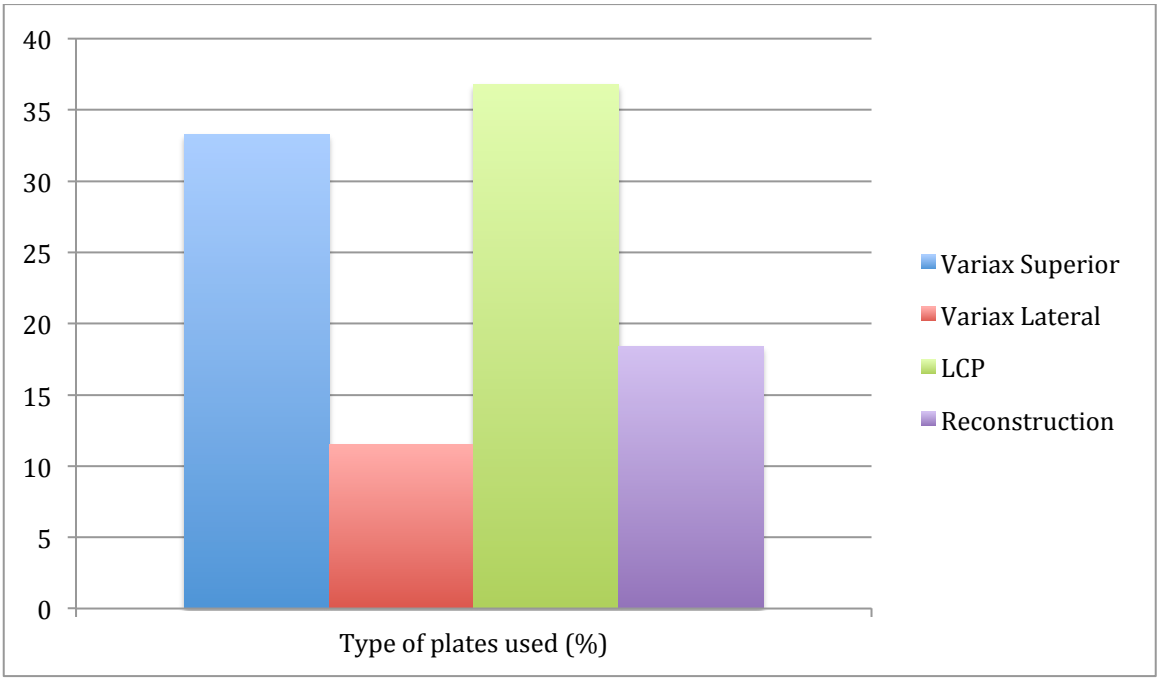

***Figure 35** : Distribution of types of plates used*

C. FOLLOW-UP

Mean follow-up duration was 21,9 months, ranging from 3 to 60 months.

D. HARDWARE REMOVAL

Hardware removal procedure was performed in 28 patients (33,7 %). These procedures were performed when requested by the patients.

Mean time of hardware removal was 14,3 months after the initial plate fixation.

Three patients presented a new fracture after hardware removal, respectively at 5, 7 and 15 days, giving a hardware removal-related complication rate of 10,7 %.
For these patients, the plate had been removed respectively at 6, 11 and 13 months after the fixation.

These three patients went under a new plate fixation with iliac crest bone grafting, with eventual healing of the fracture in all cases.

III. COMPLICATIONS

A. OVERALL COMPLICATION RATE

Seven out of the 83 patients presented a complication during follow-up, resulting in a global rate of complication of 8,4 %.

Mean time elapsed before occurring of a complication was 1,9 months (ranging from 2 weeks to 4 months).

Among the usual complications seen in literature, our study found no case (n = 0) of :

- Surgery-related vascular injury
- Surgery-related neurological injury
- Fixation-related hardware failure

However, three patients presented hardware failure due to extrinsic factors, independent from the surgical treatment.
One patient had a case of hardware failure 3 weeks after the surgery due to an epileptic seizure.
One patient presented hardware failure 2 days after the surgery due to a fall on his operated shoulder. This patient had a chronic neurological muscular weakness inducing iterative falls.
Finally, one patient fell on his operated shoulder 3 months after the fixation, resulting in hardware failure and iterative fracture.
All three patients went under iterative plate fixation with eventual healing, except the last patient who presented nonunion and had to be re-operated (with iliac crest bone grafting and plate fixation).

These last three cases were not considered in our study as plating-related complications for due to extrinsic factors that would have also complicated any other type of treatment (intramedullary fixation or nonoperative treatment).

Bone healing was achieved in all 83 patients.

B. MALUNION

Rate of malunion in our study was 1,2 %.
One patient presented a case of malunion, 3 weeks after the surgery, due to a minimal angulation (15°) of the fracture site (**Figures 36 A and B**).
This complication resulted in a slightly angulated bone-healing callus, with absolutely no functional consequences, but with a small bumpy external aspect of the clavicle.
The patient was not re-operated.
This case was consequently defined as a minor complication.

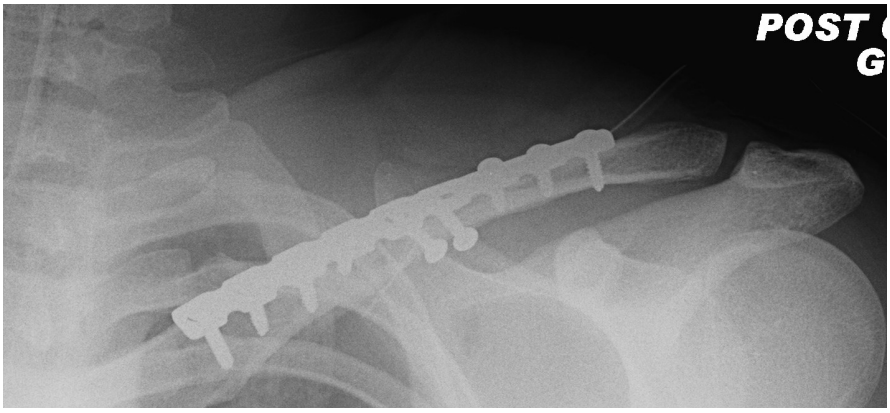

***Figure 36 A** : Immediate postoperative x-ray before occurring of malunion*

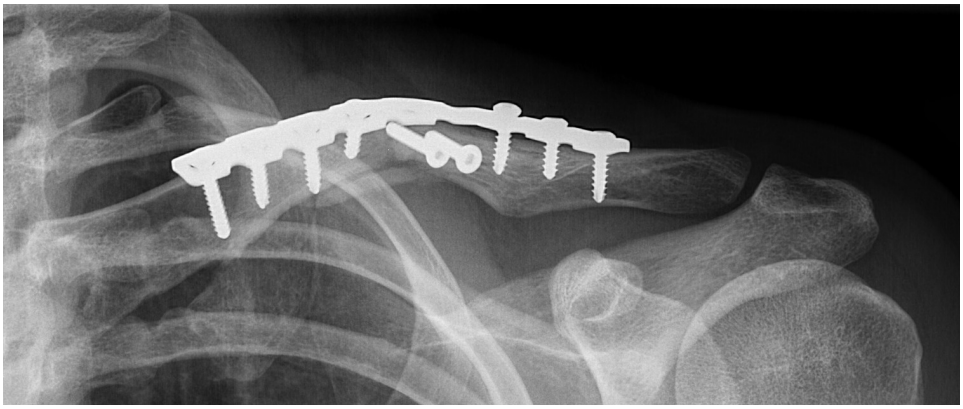

***Figure 36 B** : Only case of malunion in the present series*

C. DYSESTHESIA

Rate of post-operative dysesthesia was 1,2 %.
Cutaneous dysesthesia around the scar occurred in one patient, and completely disappeared within 3 months after the surgery.
This patient was obviously not re-operated, and occurring of post-operative dysesthesia entered in the minor complication category.

D. INFECTION

Infection was the first cause of complication in our study, occurring in 3 patients, with a rate of 3,6 %.

One patient had a superficial wound infection, which required reoperation 4 weeks after the fixation, without hardware removal.
One patient presented a deep infection 2 weeks after the surgery, which required reoperation and hardware removal. Fracture healed thereafter without any other complication (especially no nonunion or malunion).

One patient had a deed infection 6 weeks after the surgery, and was re-operated. Reoperation consisted in surgical site washing and plate substitution, with eventual good evolution.

In all three patients, reoperation was associated with sustained antibiotic treatment.

E. NONUNION

Nonunion was the second major complication behind infection.
Two male patients (2,4 %) presenting each a 2B1 type fracture treated with the use of a reconstruction plate did not achieve bone healing and experienced chronic pain and shoulder disability. Standard x-rays showed absence of fracture healing signs (**Figure 37**) and diagnosis of fracture nonunion was confirmed 4 months after the initial plating. Both patients went under a second procedure consisting in iterative plating with iliac bone grafting (**Figure 38**).
Bone healing was thereafter achieved in both patients, without functional impairment subsisting.

***Figure 37 A** : Fracture nonunion 4 months after the plating*

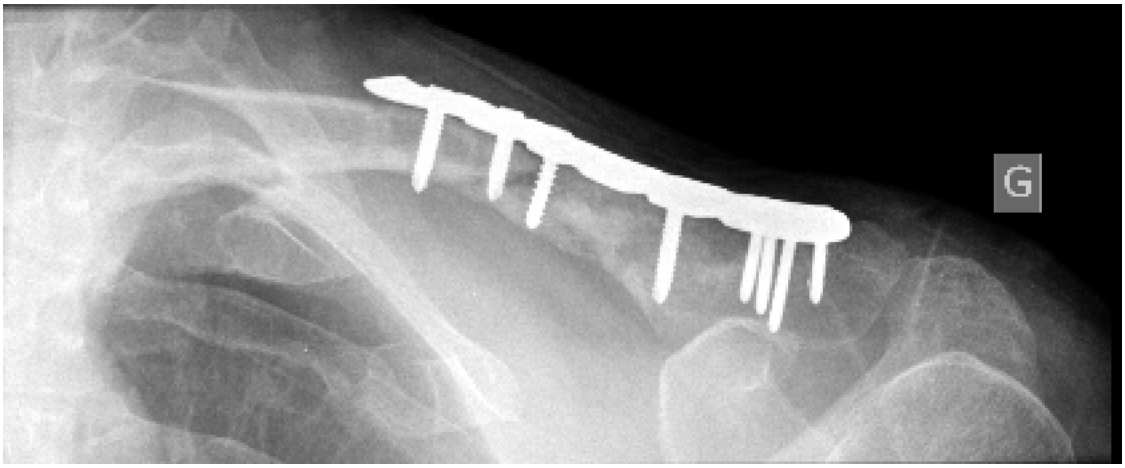

***Figure 37 B** : Bone healing achived after iterative plating and bone grafting*

***Figure 37 C** : Final aspect after plate removal*

F. REOPERATION RATE

Reoperation rate was 6 % (n = 5). All reoperation cases were due to infections or nonunion.

Mean reoperation time after the initial plating was weeks (ranging from 2 weeks to 4 months).

There was no reoperation due to malunion or iatrogenic neurovascular lesions.

Major complication rate was 6 % (3 cases of surgical site infection and 2 cases of nonunion).

Minor complication rate was 2,4 % :

- Asymptomatic minimal malunion with insignificant cosmetic impairment in 1,2 %
- Cutaneous dysesthesia with complete regression within 3 months in 1,2 %

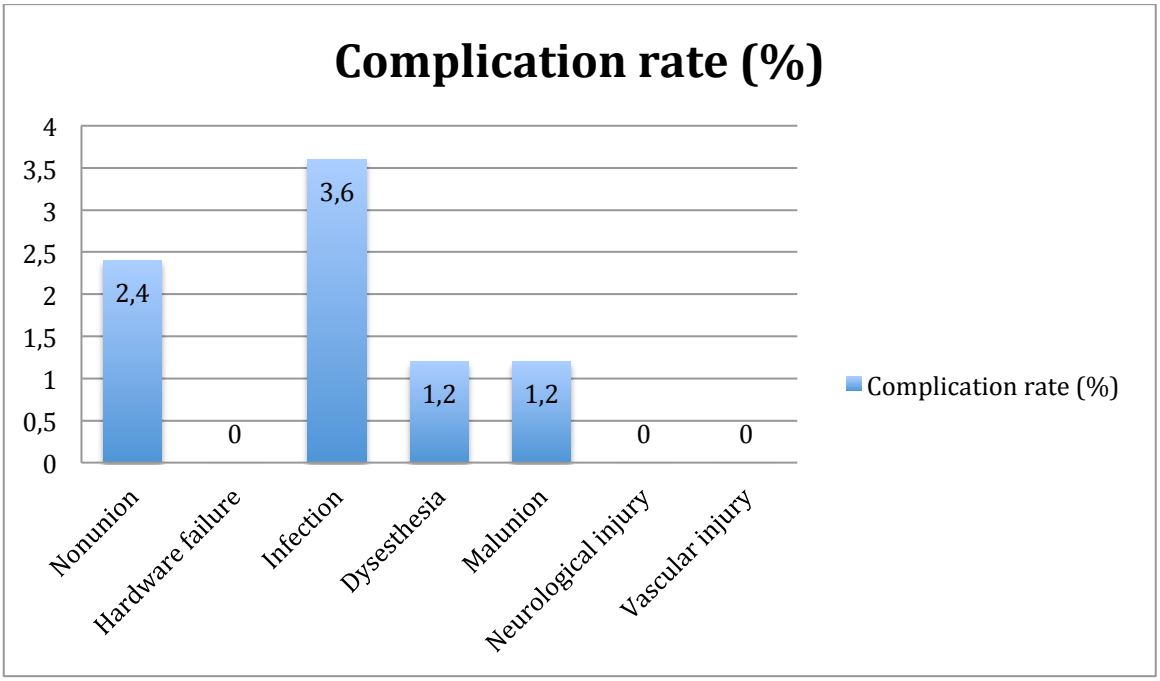

Figure 38 *: Complication types and rates in the series*

G. STATISTICAL CORRELATION

Statistical correlation was calculated between patients, fracture or treatment characteristics and rate of complication.

Correlation was searched through Pearson correlation test, Fisher exact test and t-test, with no correlation with occurring of complication being the null hypothesis.

There was no statistical correlation with occurring of a complication and :

- Patient gender
- Age
- Cause of injury
- Mono-injured, poly-injured or poly-trauma status
- Robinson type of fracture
- Presence of an initial complication
- Time before surgery
- Type of plate used

In all cases, statistical analysis resulted in absence of correlation, with a p-value > 0,1. Null hypothesis could not be rejected.

DISCUSSION

Our study's main objective was to assess and consider all complications directly related to plate fixation for acute displaced middle third clavicle fracture.

Despite a thorough investigation through scientific literature, we did not find many studies that specifically evaluated complication types, rates and correlation of clavicle plating for acute middle third fractures.
Most of the studies are comparative ones, based on clinical and functional results of operative versus nonoperative treatment solutions.

The main current question remaining about plating of middle third clavicle fractures is precisely the actual rates of complications due to this surgical procedure.

As it has been pointed out previously, clavicle plating is the most reliable technique for displaced fractures, for it owns the best security on the mechanical level, and it represents the only technique allowing anatomical bone reconstruction, which is a major objective of operative treatment solutions.

However, many surgeons and authors nowadays still opt for other treatment methods over plating due to reported high-rate complications.

These results were those of articles published in the 60's, and reported indeed very good results of nonoperative treatments with high patient satisfaction ; and high rate of complications (especially nonunion) due to surgical management of these fractures. [5,31,43,59]

Nonetheless, it should be noted that these studies included children in their analysis. Clavicle fractures in a pediatric population represent a completely different picture, where nonunion is extremely rare, as well as other types of complications.

Furthermore, more recent studies published during the past decades have shown far better clinical and radiological results with operative treatment than it was believed in the second half of the 20th century. [31,65]

Since then, comparative clinical outcomes have been extensively studied between surgical management and nonoperative treatment.
But relatively few studies have specifically and precisely assessed plate fixation-related complications.

The largest series found in recent literature emanates of Zlowodzki et al., who performed in 2005 a review of 2144 acute midshaft clavicle fractures, among which 460 were plated.
Global rate of complication in the plate group was 9 %.
Infections represented half of the complications with a proportion of 4,6 %.
Hardware failures and nonunion rates were 2,2 % for both complications. [77]

These results are strongly similar to our results, and thus confirm the representative feature of our series and our results analysis.

Böstman et al., in 1997, published their series of 103 patients. Their overall complication rate was 23 % (with 5 % of nonunion and 7,8% of infections). However, theses results included complications due to hardware removal, which we chose in our study to consider as non-directly related to the plating. [9]

Similar results were found in Poigenfürst et al. publication in 1992. Based on a series of 122 fractures, global complication rate was 20%.
Complications were : angulated malunion (9 %), infection (7 %), and nonunion (4 %).
They also reported a 3,2 % rate of iterative fracture following hardware removal.
Patients who suffered from a complication had completely identic functional results after adequate treatment.

According to the authors, almost all complications are consecutive to technical errors, especially poor choice of hardware and bone fragments devitalization. They suggested that acute bone graft could be a wise artifice for displaced comminuted fractures, in order to avoid nonunion or delayed union. [50]

A larger series of 232 middle third clavicle plating fixations was published in 1999 by Shen et al. Their complication rate was 21 %, with a vast majority of cutaneous dysesthesia (12 %), followed by malunion (6 %) and nonunion (3 %). Infection-type complications represented only 0,4 % of all complications. No iatrogenic vascular or nerve damage was observed.
Mean radiological bone healing was achieved in 10 weeks.
Hardware removal was performed in 73,7 % of the patients, at a mean time of 401 days after the plate fixation. [61]

In more recent studies, the Canadian Orthopaedic Trauma Society (COTS) published in 2007 a series of 62 patients treated by plating.
Results found a 18 % high complication rate, but then again balanced between major complications (2 % of hardware failure, 3 % of nonunion, 5 % of infection), and minor complications (8 % of dysesthesia).
Reoperation rate in this study was 10 %. [10]

A publication by Ferran et al. in 2010 found a relatively high rate of complication, with an overall rate of 27 %.
Among these complications, there were 20 % of superficial infection and 7 % of cutaneous numbness.
This was a small series of only 15 patients.
Hardware was removed in 53 % of patients, but complication-related reoperation rate was 20 %. [18]

In 2011, Kulshrestha et al. issued a 45-patients series where complication rate was 13 % overall.
There were 9 % of hardware failure and 4 % of malunion. Reoperation rate was 9 % (patients with hardware failure).
No infection was found during follow-up. [32]

Wijdicks et al. showed in their series of 43 patients a rate of complication reaching 23 %. Hardware failure was then the first complication (14 %), followed by dysesthesia (7 %), and infection (2 %).
Twelve percent (12 %) of the patients were reoperated due to a complication. [71,72]

Two studies published in 2013 (respectively of 27 and 37 patients) found excellent results in terms of complication, with no complication at all during follow-up. [13,14]
The authors from both studies reports no complication of any kind, 100 % of bone healing and fast recovery.

Fridberg et al. also reported very low complication rate in a 105-patients series, with only 1 % of superficial infection and 5 % of hardware failure, and no nonunion, dysesthesia or numbness. Reoperation rate was of 5 %.
Hardware removal (non related to a complication) rate was of 31 %. [20]

Persico et al. published a study similar to ours, assessing complications of clavicle plating in a Level-I Trauma Center, in a series of 56 patients.
Reported conditions of treatment and follow-up were similar to our study. Mean time between injury and surgery was 11,9 days.
Results found a higher global complication rate compared to ours, being of 21,4 %.
Complications were of three types : 7,1 % of infection (deep or superficial), 7,1 % of nonunion, and 7,1 % of hardware failure.
However, reoperation rate was of 8,9 %. [49]

Two other recent publications found comparable results to ours :

Ashman et al. reported a 6,8 % high complication rate, with only 2,8 % of patients who were reoperated. Reoperations were due to malunions and hardware failures. No nonunion or infection were seen during follow-up.
Just as our analysis, no correlation was seen between rates of complication or reoperation and age, gender, type of fracture, or type of plate used. [6]

Ranalletta et al. reported a 8,9 % high complication rate. Major complications rate was of 6 %, among which there was one case of subclavian vein extrinsic compression, one case of nonunion, and one case of hardware loosening. [52]

The latest study was conducted by Wolf et al. in 111 patients treated exclusively with 3.5 mm reconstruction plates.
The authors reported a rate of implant failure of 12,6 %, higher than found in literature. They concluded in their analysis that this high rate of implant failure was attributable to the exclusive use of reconstruction plates, which have a supposedly lower biomechanical safety than other stronger plates.
For other complications, rates were similar to those found in other studies.
Reported rate of plate removal was 37,8 %. [73]

Different results of the main last studies are summed up in **Table 1**.

	n	Overall	Hardware failure	Nonunion	Malunion	Infection	Dysesthesia	Neurological	Vascular	Reoperation
Poigenfürst 1992	122	20 %	0 %	4 %	9 %	7 %	-	0 %	0 %	-
Böstman 1997	103	23 %	0 %	5 %	-	7,8 %	-	0 %	0 %	17,7 %
Shen 1999	232	21 %	0 %	3 %	6 %	0,4 %	12 %	0 %	0 %	-
Zlowodski 2005	460	9 %	2,2 %	2,2 %	0 %	4,6 %	-	0 %	0 %	-
COTS 2007	62	18 %	2 %	3 %	0 %	5 %	8 %	0 %	0 %	10 %
Ferran 2010	15	27 %	0 %	0 %	0 %	20 %	7 %	0 %	0 %	20 %
Kulshrestha 2011	45	13 %	9 %	0 %	4 %	0 %	0 %	0 %	0 %	9 %
Wijdicks 2012	43	23 %	14 %	0 %	0 %	2 %	7 %	0 %	0 %	12 %
Douraiswami 2013	27	0 %	0 %	0 %	0 %	0 %	-	0 %	0 %	0 %
D'Heurle 2013	37	0 %	0 %	0 %	0 %	0 %	-	0 %	0 %	0 %
Fridberg 2013	105	6 %	5 %	0 %	0 %	1 %	-	0 %	0 %	5 %
Persico 2014	56	21,3 %	7,1 %	7,1 %	-	7,1 %	-	0 %	0 %	8,9 %
Ashman 2014	143	6,8 %	1,4 %	0 %	1,4 %	0 %	4 %	0 %	0 %	2,8 %
Ranalletta 2015	72	8,9 %	1,5 %	1,5 %	0 %	1,5 %	2,9 %	0 %	1,5 %	-
Woltz 2016	111	21,6 %	12,6 %	2,7 %	4,5 %	0,9 %	-	0 %	0,9 %	9 %
Herzberg 2016 ***Present study***	83	8,4 %	0 %	2,4 %	1,2 %	3,6 %	1,2 %	0 %	0 %	6 %

Table 1 *: Plating-related complication rates found in literature*

These results are, for the most part, highly comparable to those of our series.
In the most recent studies, global complication rate seems to be contained below 10 %.
Some studies report higher rates, from 20 % to 27 %. These higher rates are frequently explained by including hardware removal-related complications in the final results.

Our study found an overall complication rate of 8,4 %, very similar to the latest publications [6,20,52], and even lower than reported in some publications.
The same finding was drawn concerning major and minor complication rates.

In an almost constant manner, infection is the most frequently reported complication, with rates ranging from 0 % to 20 % of all complications, and being of 3,6 % in our study.
Infections, when occurring, are almost always major complications, requiring reoperation in order to detect and treat a deep septic process, well often with plate removal or plate substitution.
Infection-type complications are frequently badly received for the patients, who usually consider infection as a direct iatrogenic event.
In our study, the 3 patients who developed an infection had a primary plate fixation because they could not be managed otherwise. Benefit-risk balance was in favor of surgical treatment in all cases.
Nevertheless, even in plain surgical indications, information of the patient is essential and informed consent should be obtained as often as possible.

Another frequent complication is occurring of dysesthesia and/or numbness of the scar and skin around the scar, with rates going up to 12 % in some studies.
However, being a minor complication and wearing off almost constantly in a few weeks time, it is well possible that cutaneous dysesthesia and/or numbness are under-diagnosed.

Hardware failure and malunion are relatively rare complications of clavicle plating, based on this review.
Brachial plexus and subclavian vessels injuries are extremely rare, almost non-existent, but caution has to be taken given the potential severity of these complications.

One of the major facts of this analysis is the relatively very low rate of nonunion. Nonunion has indeed been for decades a supposedly frequent complication of clavicle plating, and still is a source of reluctance for some surgeons. [26]
However, the review of the recent literature presented above show quite clearly that nonunion rates are very low in plate fixation, almost constantly below 5 %, and being of 2,4 % in our series.

It seems, given the recent analysis found in literature, that plate fixation of middle third clavicle fractures tends to have a better benefit-risk balance that nonoperative treatment or even intramedullary fixation, regarding displaced fractures.

In addition to the superiority of biomechanical safety fixation [11,15,64], several studies found better results (complications and clinical outcomes) with plates rather than intramedullary fixation.

Some authors reported lower rates of infection and cutaneous complications with intramedullary fixation [70,34], but the majority of comparative publications between intramedullary fixation and plating found either equivalent results or superior results with the latter method, in terms of functional results as well as complications. [8,16,18,31,35,65]
Ferran found that intramedullary hardware removal was, counter to plate fixation, mandatory. [18]
Millett reported complication rates up to 26 % for intramedullary fixation, with an increased risk of nonunion (9 %) requiring reoperation. [39]

These findings are, once again, applicable for displaced or comminuted midshaft fractures, but could be discussed concerning non-displaced fractures.

Regarding nonoperative treatment results in terms of complications, there is much more significant difference in recent scientific literature.

Hill et al. published in 1997 extremely poor results of nonoperative treatment for acute middle third clavicle fractures. [27]
They reported nonunion rate of 15 %, malunion rate of 31 % with all malunion cases being symptomatic on a functional level, 29 % of plexus irritation signs, and a 21 % rate of secondary surgery for cosmetic reasons.
Furthermore, 25 % of the patients had chronic residual pain.
The authors proposed consequently to their findings that initial shortening of 20 mm or greater was associated with nonunion and/or unsatisfactory results.

Robinson et al. deeply studied the risk of nonunion of clavicle fracture. Concerning diaphyseal fractures, they reported a rate of 4,5 %.
The authors used their database to identify risk factors for nonunion. Their findings were that female gender, age, comminution and displacement (lack of cortical apposition) were independent risk factors of nonunion. [57]

In their 2009 publications, the same authors extended their work and found even more eloquent numbers while calculating the probability of nonunion with nonoperative treatment (**Table 2**). [31]

	Non displaced No comminution		Displaced Comminuted	
Age	Male	Female	Male	Female
20	< 1 %	2 %	18 %	30 %
30	< 1 %	3 %	20 %	35 %
40	1 %	5 %	25 %	38 %
50	2 %	6 %	29 %	40 %
60	2 %	7 %	31 %	44 %
70	4 %	10 %	35 %	49 %

***Table 2** : Probability of nonunion depending on risk factors, established by Edinburgh Royal Infirmary authors*

Predictive factors were also studied by Murray et al., whose findings were similar to those above, but with smoking in addition to them. [42]

Lazarides and Zafiropoulos reported high unsatisfactory results with nonoperative treatment. In their series, shortening malunion occurred in 26 % and was responsible of clinical impairments such as loss of strength, residual pain, decreased range of motion, and cosmetic dissatisfaction.
Mean shortening in healed clavicles was 14,4 mm in male patients and 11,2 mm in female patients.
Unsatisfactory clinical results were strongly associated with shortening greater than 18 mm in male patients and 14 mm in female patients. [33]

Shortening of the clavicle is a major unwanted consequence, when union has been achieved.
Many studies proved the functional impairment of shortened malunion, with unsatisfactory outcomes on range of motion, pain, appearance, and global balance of the scapular girdle.

Most authors propose a threshold of 10 to 15 mm that can be accepted, to discuss according to the type of patient and functional needs.
Shortening greater than 15 mm has a major risk of nonunion, and unsatisfactory results if bone healing is reached.
George et al. insisted on the fact that this threshold has to be lowered when optimal function of the shoulder is required. [4,22,29,33,36]

Altamimi et al. reported less nonunion and malunion cases with plate fixation in a controlled randomized trial on a 132 patients-series.
They also assessed faster bone healing (16,4 weeks versus 28,4 weeks) in the plate group, and improved clinical scores at all time during the follow-up. Patient global satisfaction was higher in the plate group. [3]
Identical results were reported in several studies of high level of evidence, reviews, and meta-analysis. Some studies found a risk reduction for nonunion of 86 % with clavicle plating compared to nonoperative treatment for displaced fracture. Even for nondisplaced fractures, risk reduction was significant (57 %). [16,35,38,54,55,74]

Another randomized trial was performed by Mirzatolooei in 2011, with yet another analysis supporting plate fixation over nonoperative treatment.
Nonunion rate was relatively low (4,2 %), but malunion rate was extremely high (79,2 %), with 75 % of unsatisfied patients in the nonoperative treatment group.
In their own randomized trial (plate versus sling), Virtanen et al. reported a higher rate of nonunion in the plate group (24 %), but no significant difference in function or disability after treatment at one-year follow-up. [40]

Althausen et al. published a highly interesting study in 2013, regarding clinical and financial outcomes of nonoperative versus surgical treatment.
On the clinical level, patients treated non-operatively had a higher rate of nonunion (4,8 % versus 0 %).

Nonoperative treatment had also less satisfactory results for chronic pain (25,3 % versus 6,1 %), cosmetic deformity (32,5 % versus 18,2 %), weakness (33,7 % versus 10,6 %), and loss of motion (31,3 % versus 15,2 %).

Patients from the nonoperative treatment group took more pain medication and required more physical therapy.

On the financial level, results were then again quite eloquent : operated patients missed fewer days of work (8,4 days versus 35,2 days), and mean income lost was 322 $ versus 10.506 $. The overall cost for operated patients was 12.977 $, versus 18.068 $ for non-operated patients, saving more than 5.000 $ for each patient in the surgical group. [4]

	n	Overall	Nonunion	Malunion	Neurological	Vascular	Reoperation
Hill 1997	52	46 %	15 %	31 %	29 %	0 %	21 %
Robinson 2004	581	-	4,5 %	-	-	-	-
Lazarides 2006	132	39 %	13 %	26 %	-	-	-
Altamimi 2008	49	32,7 %	14,3 %	18,4 %	0 %	0 %	-
Mirzatolooei 2011	24	83,4 %	4,2 %	79,2 %	0 %	0 %	-
Virtanen 2012	32	-	24 %	-	-	-	24 %
Althausen 2013	83	37,3 %	4,8 %	32,5 %	0 %	0 %	0 %
Robinson 2013	100	-	16 %	-	-	-	-
Melean 2015	41	-	9,6 %	-	-	-	9,6 %
Herzberg 2016 ***Present study***	83	8,4 %	2,4 %	1,2 %	0 %	0 %	6 %

Table 3 *: Nonoperative treatment complication rates found in literature, compared to this present study*

This analysis of nonoperative treatment for displaced middle third fractures of the clavicle show quite evidently the increased risks of nonunion and malunion associated with this method.

There is nowadays too much evidence of superiority of the plate fixation over nonoperative treatment for displace and/or comminuted fractures to recommend non-surgical management of these injuries.

Intramedullary fixation does not seem like a reasonable choice for displaced or comminuted fractures, due to the lack of anatomical reconstruction and sufficient mechanical resistance.

Plate fixation appears to be the gold-standard method for these fractures.
Plate fixation can be performed through different ways :

- Superior versus anteroinferior approach
- Open versus minimally invasive

Recent studies on the subject showed no difference in terms of complications and clinical results (length of procedure, nonunion, wound complications, bone healing time, clinical scores, etc.). [19,30,62]

In the same way, most studies found that the type of plate used does not seem to influence on occurring of complications, as it was the case in our analysis.
However, recent studies concluded to a supposedly superior biomechanical safety with pre-contoured locking or not-locking compression plates over reconstruction plates, with higher risk of implant failure when using 3.5 reconstruction plates, especially in patients or fractures presenting risk factors for complications (e.g. smoking, osteoporosis, comminuted fractures). [11,15,64,73]

Time before plate fixation has been questioned regarding its role in occurring of complications and final clinical outcomes, but our study did not found any correlation, just like recent publications on the subject. [12]

Nonoperative treatment allows to overcome surgery-related complications (mainly infections and wound-healing process complications).
However, this method of treatment is large provider of nonunion (almost constantly responsible of chronic pain and disability), as well as malunion that can be angulated or

shortened, with extremely substantial harmful consequences (painful, functional, or cosmetic).

Plate fixation benefits clearly of an undeniable superiority over nonoperative treatment for acute displaced middle third clavicle fractures, especially in terms of nonunion and malunion.
These good results come, in rare cases, with the cost of surgery-related complications, such as infections or skin complications, which are almost always treated successfully without aftermath.
Overall, it seems that the benefit-risk balance is widely acceptable.

This argument is even stronger given the fact that the vast majority of middle third clavicle fractures occur in young and very active patients, who will afterwards need a perfectly functional shoulder, in order to return to previous physical activities (sport, work, or leisure) with the same level of ability.

Professional athletes are a very good example of treatment evolution for these fractures. Several publications studying results of surgical or nonoperative treatment in professional athletes showed great improvement of rehabilitation with plate fixation compared to non-surgical management.

Morgan et al. published a review of middle third clavicle fractures in the National Football League (USA), on a five-year period.
While comparing healing and rehabilitation of players treated by plate fixation versus players treated nonoperatively, the authors found that players treated surgically had a faster bone healing (mean time of 8,8 weeks) and 50 % of these players returned to play at their initial position during the same season.
Whereas players treated nonoperatively had a slower bone healing (only 43 % were considered healed after 13,3 weeks), and 57 % of these players refractured their clavicle within one year after their initial injury, missing an average of 1,5 seasons. [41]

Other studies also found results supporting surgical plating management of these fractures in professional athletes.
Meisterling et al. reported excellent results in professional athletes treated by plating, with 100 % of patients returning to sport at the same level in a mean time of 83 days (67 % before a 12-weeks time after the surgery), with no complication of any kind. [37]

Ranalletta et al. had similar results, with a rate of 94 % of patients treated with pre-contoured plates who returned to their same level of sport, in a mean time of 68 days. They reported a hardware removal of 9,3 %. [53]

Hardware removal is another important point of discussion concerning plating of midshaft clavicle fracture.

We reported in our results few but nonetheless existing complications due to hardware removal procedures.
Our hardware removal rate was 33,7 %, which is concordant with scientific literature. Among these procedures, we reported a 10,7 % rate of complication (three cases of refracture). This rate is also concordant with results found in most publications.

This matter should not be underestimated or misjudged, and hardware removal procedures must not be considered as harmless.
Though, in our opinion, hardware removal is not to be looked at as a complication itself, it should be regarded as a potential source of – fortunately – relatively rare complications.

Wang et al. studied comparative functional outcomes and global satisfaction between patients initially treated with clavicle plating whom had secondarily their plate removed and patients who had not.
The authors did not find any significant difference between both groups.

Their recommendation was accordingly to leave the plate untouched unless strongly requested otherwise by the patient. [69]

In the latter case, when plate removal is requested, the removal procedure should not be performed before a 12-months period after the fixation.
Once the plate removed, the risk of refracture must be limited by avoiding all kinds of physical activity during a 4-weeks period.
Patients must absolutely be warned about risk of complications (especially refracture and infection) before considering the removal procedure.

The Edinburgh classification of clavicle fractures introduced by Robinson could also be discussed at this point.
Robinson indeed proposed this very pertinent classification finding high correlation with increased risk of nonunion in 2B types, and even higher risk with 2B2 types compared to 2B1 types.
However, these findings are relevant when studying nonoperative treatment results. Differences between 2B1 and 2B2 types are not found when assessing results of surgical treatment.

Differencing 2B1 and 2B2 types could thus not be as relevant as imagined regarding treatment decision.
The most important criteria to assess are the displacement characteristics.

Our criteria of fracture displacement were twofold :

- Significant shortening (10 mm or greater)
- Significant vertical displacement (100 % of the clavicle height or greater)

Fractures indexed as 2B types according to Robinson criteria are displaced fractures that will in all cases present both features listed above.
Whether they are 2B1 or 2B2 types, they will present an increased risk of complication (especially nonunion and malunion) if treated nonoperatively, and should consequently go under plate fixation.

Furthermore, the secondary purpose of our analysis was to classify every middle third fracture using Robinson classification, and see if all fractures observed could be well described.
We found in our analysis one particular type of fracture that is not well described by any classification

This type of fracture is located at the union of middle and lateral thirds of the clavicle, more precisely in the lateral part of the middle third opposite the medial edge of the coracoid process, and frequently occurs in a displaced fashion.
Though they are not lateral third fractures *per se*, these fractures could be associated with type II or IV of Neer classification of lateral third fractures.
However, their anatomic location (i.e. more medial than Neer type IV description) and their biomechanical characteristics require a specific treatment with metaphyso-diaphyseal plate fixation, much more similar to Robinson type 2B1 fractures management (**Figures 39 and 40**).
Nonetheless, their treatment differs to 2B fractures management due to an overly lateral location, forbidding the use of diaphyseal plates.
We recommend plate fixation using lateral anatomic locking plate to treat these fractures, which should be considered overly lateral to be described as 2B types according to Robinson, and overly medial to be described as type II or IV of Neer distal fractures classification.

***Figure 39** : Lateral middle third fracture*

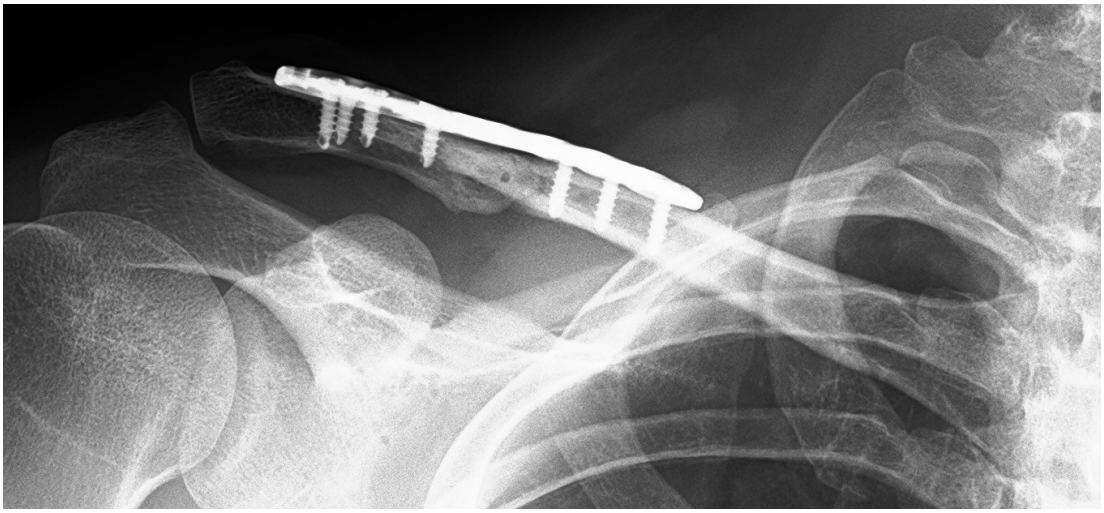

Figure 40 *: Same fracture after open reduction and internal fixation using a lateral anatomic locking plate*

Prevalence of such fracture is quite substantial, thus so is the importance of describing a safe, reproducible technique to treat these fractures.

In our series, among 87 cases analyzed, there were 8 fractures of this type, resulting in a 9,2 % prevalence.

Traumatology surgery has witnessed a true evolution regarding middle third clavicle fractures, which have been treated nonoperatively for decades, and are nowadays subject to many studies supporting surgical fixation.

While studies reporting evidence in favor of internal fixation are more and more numerous, there is nowadays no recent study supporting nonoperative treatment for displaced fractures.

When looking at studies from the second half of the 20th century, decision-making criteria for surgical treatment were quite limited.

Ali Khan and Lucas recommended in 1978 several indications to be considered as reasons for internal fixation using superior plating :

- Neurological reason (symptoms of brachial plexus involvement)
- Vascular reason (ischemia of the arm)
- Skin in jeopardy
- Gross displacement with comminution
- Fracture of both clavicles
- Severe persistent pain

At the time, authors already found excellent results of internal fixation, with 100 % of bone healing, no infections, no hardware failures, vanishing of all neurovascular disorders, and almost complete pain relief within 12 hours. [1]

Zenni et al. reported a similar list of surgical indications, adding the notion of patient inability to tolerate prolonged immobilization (required by nonoperative treatment). [76]

With time, technique evolutions, development of less prominent plates, and changes in the global approach of traumatology and rehabilitation, indications evolved to become more accurate and ample.
Facing a young and active population, with high expectancy regarding their functional skills, indications for internal fixation grew larger.

Current indications for surgical plating of middle third clavicle fractures could be listed as following, with always keeping in mind that the treatment method should be chosen according to the patient's activities and needs : [65]

- Neurological (brachial plexus) disorder
- Vascular (subclavian vein or artery) disorder
- Skin in jeopardy
- Open fracture
- Floating shoulder
- Fracture of both clavicles
- Displacement ≥ 100 % of the clavicle thickness
- Shortening ≥ 10 mm
- Strong angulation with bumpy aspect
- Comminuted fracture
- Hyperalgic patient, non-relievable pain
- Patient's inability to tolerate immobilization
- Optimal function needed in the shoulder
- Need for fast recovery, rehabilitation, and return to activities

With this amplified list of indications, it is evident that many patients suffering from a middle third clavicle fracture will present at least one of these criteria.

For these patients, plate fixation will represent a reliable technique, allowing good immediate and long-term results, with a highly favorable benefit-risk balance regarding the matter of complications.

CONCLUSION

Middle third clavicle plating is the most common surgical technique for acute fracture surgical treatment.
Though it allows anatomical reconstruction and stable mechanical fixation, this technique is not without complication.

Scientific literature reports, in some cases, high rates of complications due to use of plates for acute fractures of the middle third of the clavicle. Common reported complications are : nonunion, infection, scar-healing delay, dysesthesia, hardware failure.
Based on these data, some authors continue to avoid plate fixation, and choose other treatment options, such as intra-medullary fixation or nonoperative treatment.

Specific assessment of these potential complications is necessary to improve treatment decision and technique choice.

This study is based on a 87-patients retrospective consecutive monocentric series. Patients were aged 16 to 73 (mean 32,9) and gender distribution was 80,5 % of men for 19,5 % of women.
These patients were treated by superior plating for acute displaced middle third fracture of the clavicle in the Orthopedic and Traumatology Surgery Department of Edouard Herriot Hospital, Lyon, France, between June 2008 and March 2016.
Plate fixation was performed within a mean time of 7,9 days after the injury.

All fractures were displaced (type 2B of Robinson classification) : 66,7 % of 2B1 types and 33,3 % of 2B2 types.

All patients were clinically and radiologically assessed during a mean follow-up of 22 months.
One patient was lost to follow-up and 3 had not completed the minimal follow-up duration at the time of the survey.

Rates and types of complications directly related to plate fixation were evaluated among 83 patients.

Results analysis of this study conclude to several notable facts :

- Overall complication rate was 8,4 %, which is quite similar to complication rate found in recent studies
- There were no neurological or vascular complication (brachial plexus or subclavian vessels injury)
- There were no osteosynthesis-related hardware failure
- Only one case of malunion occurred, and revealed to be completely asymptomatic, not requiring any reoperation
- On case of dysesthesia was noted, with complete regression within 3 months
- There were two cases of nonunion (2,4 %), diagnosed 4 months after the surgery. Both patients were secondarily reoperated and healing was obtained through iliac bone grafting and new plate fixation.
- Infection was the only type of major complication, occurring in 3 patients (3,6 %). Two patients had deep infection requiring reoperation : hardware removal and iterative plating in the same time in one case, and hardware removal without plate substitution in the other case, with good final results in both patients. One patient presented a superficial infection, requiring surgical site washing and debridement, without plate removal.
- Major complications (i.e. infection cases and nonunion cases in this study) rate was 6 %, and minor complications rate was 2,4 %.
- Reoperation rate due to a major complication was 6 %.

These results show relatively low rates of complication directly due to plate fixation for acute middle third clavicle.
These good results are sometimes achieved with the cost of few complications (infection and nonunion cases in this study), but with far better outcome in terms of nonunion and

malunion than nonoperative treatment (respectively over 15 % and 15-20 % in modern literature).
This last element is extremely important to consider, given that these fractures occur in a very large proportion in a young and active population, where functional consequences of nonunion and shortened or angulated malunion can be catastrophic.
Superior plating is reliable, allowing anatomical and mechanical satisfactory results.

Plating-related complications need to be carefully assessed during follow-up, in order to avoid complications aftereffects. One must know every type and risk of complication that could occur after plate fixation, and information must absolutely be given to the patient. Benefit-risk balance has to be thoroughly estimated.

Finally, hardware removal procedures are not always harmless, and caution must be taken when removal is requested by the patient and is considered. Risk of refracture is not insignificant, and has to be taken in consideration along with the patient's motivation.

Along with the results of this study, techniques evolution and complications assessment of operative and nonoperative treatment of displaced middle third clavicle fractures have shown these past years that superior plating is a reliable method, and its validity is one more time comforted by this study.

Our analysis also allowed identifying a particular form of fracture, located at the lateral part of the middle third, not well described by current classifications. This type of fracture is not compatible with usual middle or lateral third fractures fixation technique.
After our specific analysis of these fractures, we recommend a surgical fixation using an anatomic lateral plate.

In conclusion, types and rates of complications of this series are highly similar to those found in recent literature.

Low rate of complications and good functional results of plate fixation both support this latter method to treat acute displaced middle third clavicle fracture, with a superior benefit-risk balance compared to nonoperative treatment in an often young and active population.

The main alternative to plate fixation is represented by intramedullary fixation, but this method has limitations of its own, especially biomechanical and anatomical incompatibility with some displaced or comminuted fractures.

Plate fixation seems to have less limitations and better outcomes than nonoperative treatment and intramedullary fixation.

However, occurring of complications is a possible issue requiring thorough patient information.

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VU :
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Professeur Jérôme ETIENNE

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Pour Le Président de l'Université
Le Président du Comité de Coordination
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MERLINI Lorenzo - Complications des ostéosynthèses par plaques supérieures des fractures fraiches du tiers moyen de la clavicule

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Résumé :

Introduction Le traitement des fractures du tiers moyen de la clavicule déplacées est très controversé.
Beaucoup restent fidèles au traitement orthopédique alors que le traitement chirurgical a été défendu par plusieurs articles récents. Le risque de complications peut influencer directement la décision. Nous avons donc voulu voir si une attitude plutôt chirurgicale amenait un taux problématique de complications pouvant nous faire reconsidérer les indications.
Le but de ce travail était : 1. de colliger les complications observées après ostéosynthèses des fractures de clavicule du tiers moyen opérées dans notre service. 2. de voir si la classification de Robinson intégrait tous les types de fractures observés.
Matériels et méthodes Cette étude rétrospective sur dossiers a été menée de Janvier 2008 à Mars 2016.
Quatre-vingt-sept patients (80 % d'hommes) ont été inclus. Toutes les fractures ont été traitées par plaque sur la face supérieure de la clavicule avec un délai moyen de 7,9 jours par rapport à l'accident.
Soixante dix neuf fractures étaient déplacées (décalage de plus d'une épaisseur de clavicule et/ou chevauchement de plus d'1 cm) et correspondaient au type 2 B de Robinson. La synthèse faisait appel à une plaque de reconstruction dans 16 cas, et plaque anatomique pour tiers moyen dans 63 cas. Pour 8 fractures situées dans la partie latérale du tiers moyen, en regard du bord médial de la coracoïde ont été utilisées des plaques anatomiques latérales.
Le recul moyen était de 21 mois. Les réinterventions et complications hors ablation de matériel ont été relevées pour chaque patient.
Résultats Nous observions 5 (6%) complications majeures (2 pseudarthroses et 3 infections) ayant nécessité une ré-opération. La reprise a été suivie de consolidations dans tous les cas.
Nous observions 2 (2,4%) complications mineures (1 cal vicieux discret, 15° d'angulation centré sur le foyer de fracture sans conséquence fonctionnelle et 1 cas de cicatrice douloureuse).
Discussion Les complications majeures (6%) observées dans cette série ont un taux similaire à ceux observés dans la littérature récente. Nous avons observé un type particulier de fracture latérale du tiers moyen, non incluse dans la classification de Robinson, qui se prête mieux à une plaque anatomique latérale qu'à une plaque classique pour tiers moyen.
Ce risque minime de complications n'est cependant pas nul et il demeure important de bien informer les patients et de prendre la décision d'ostéosynthèse en connaissance de cause.

Introduction Treatment of displaced middle third clavicle fractures still lacks consensus.
Many surgeons continue to support conservative treatment, even though surgical management has been upheld by several recent studies. Complications risk may directly influence treatment decision. We wanted to study if a surgical management were responsible for a problematic complication rate that could make reconsider our indications.
The objective of this study was : 1. to assess and describe types and rates of complication related to superior plating of acute middle third clavicle fractures. 2. to see if the Robinson classification included every types of fractures observed.
Methods This retrospective study was conducted from January 2008 to March 2016. Eighty-seven patients (80 % men) were included. All fractures were treated by superior clavicle plate fixation within a mean time of 7,9 days after the injury.
Seventy-nine fractures were displaced (supero-inferior gap of more than a clavicle height and/or shortening greater than 1 cm) and considered as 2B types according to Robinson classification. Fixation was achieved with reconstruction plate in 16 cases and anatomical middle third plate in 63 cases. For 8 fractures located in the lateral part of the middle third, opposite the medial edge of the coracoid process, lateral anatomical plates were used.
Mean follow-up was 21 months. Reoperations and complications other than hardware removal were assessed for each patient.
Results We observed 5 (6%) major complications (2 cases of nonunion and 3 infections) requiring a reoperation. Healing was achieved in all cases.
Two patients (2,4%) presented a minor complication (1 case of slight malunion : 15° of angulation on the fracture site without functional impairment and 1 case of scar dysesthesia).
Discussion Major complications rate observed in this series is highly similar to those found in recent literature. We identified a particular type of fracture, in the lateral part of the middle third, not included in the Robinson classification, whose treatment is better achieved using lateral anatomical plate over a middle third anatomical plate.
This minimal risk of complication is however not inexistent, and it remains important to give the patient thorough information and make an informed decision regarding surgical treatment.

MOTS CLÉS : Clavicule ; fracture ; tiers moyen ; plaque ; complication

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