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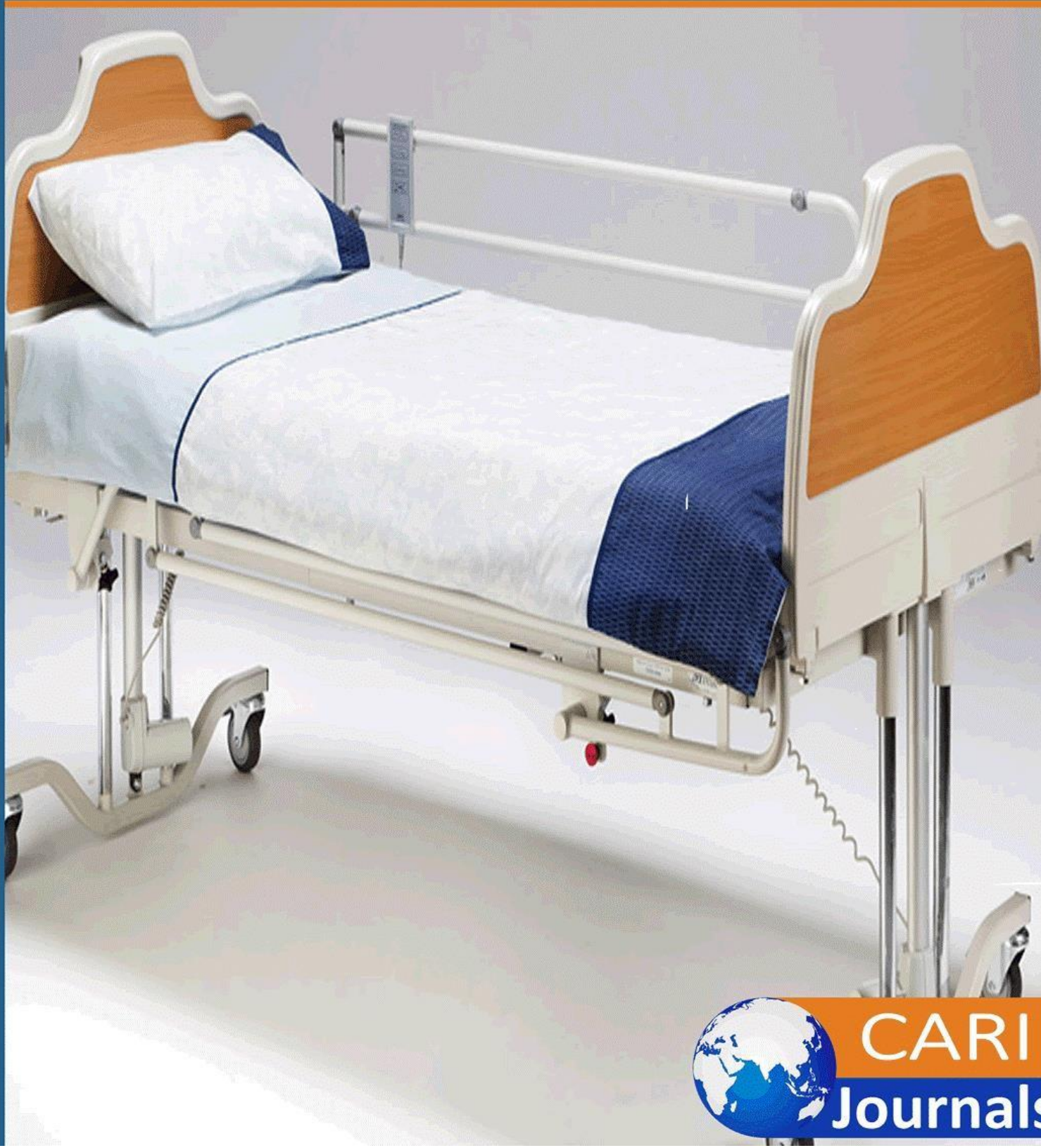

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# First – Line Papineau Technique and Honey for Late Leg Open Fractures in Mbujimayi

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## Abstract

**Purpose**: To provide evidence of the benefit of treating open fractures of moderate and complex severity using the protocol combining the Papineau technique as first-line treatment with honey, in terms of post-operative results.

**Methods**: This quasi-experimental study was carried out in three hospitals in Mbujimayi, Democratic Republic of Congo; from January 1, 2017 to March 30, 2025. It involved 91 patients admitted to the trauma department for open fractures of the leg bones and divided into three groups according to the therapeutic protocols used.

**Results**: The mean wound healing time was 46.8 ± 11.1 days for the group of patients treated with the experimental protocol combining the Papineau technique as first intention with honey, compared to the other methods (Papineau technique as first intention without honey and classical Papineau technique) whose respective wound healing times were 62.5 ± 13.1 days and 72.2 ± 9.5 days. This experimental protocol proved effective in terms of reducing the average partial weight-bearing times (9.6 ± 1.9 weeks), and obtaining sufficient bone consolidation (7.7 ± 1.0 months) as well as the average length of hospital stay of patients (5.5 ± 1.7 months). Results which are much better, compared to the other therapeutic methods under study.

**Unique Contribution to Theory. Practice and Policy**: The protocol combining the Papineau technique as a first-line treatment with honey has better post-operative results and significantly reduces the duration of patient inactivity after fracture of the leg bones, compared to other methods studied.

**Keywords:** *Open Fracture, Leg Bone, Papineau Technique, First line, Honey, Mbujimayi*

## Introduction

Fractures of the leg bones are the most common skeletal fractures of the pelvic limb [1-3]. They are often open and may involve one or both bones of the leg. Due to its subcutaneous location, the tibia is the most exposed bone. These open fractures pose the problem of both treatment of the soft tissue and fixation of the fracture site [1,4-6].

Worldwide, the incidence of open tibia-diaphysis fractures is on average 17 per 100,000 people per year. These fractures mainly affect young adults under 40 years of age, with a male/female sex ratio of 2:1 [7].

The infection rate of open tibia fractures varies from 2 to 40% depending on the series. The incidence of these infections is correlated with the complexity of the fracture, assessed by the Gustilo and Anderson classification. While fractures classified as Gustilo and Anderson 1, 2 and 3a have infection rates around 2-5%, the prevalence of infection can rise to 40% in the case of the assessed fractures Gustilo and Anderson 3c [2, 8]. It is therefore evident that the main complication of open fractures is infection, which compromises the preservation of the limb in the short term and consolidation in the medium term (septic pseudarthrosis) [9,10].

Open fractures assessed Gustilo and Anderson type 2 and 3 initially treated with conservative methods eventually become infected. This leads to a longer hospital stay and treatment duration with the resulting increased financial expenses and longer hospital stay [11,12]

In our milieu, with the proliferation of motorcycles as a common type of transport (motorcycle taxis or personal motorcycles), there are many traffic accidents causing open trauma including open fractures of the leg bones.

The main problems with these open fractures are the high frequency of infection, the ineffectiveness of the method currently used for their treatment and the heavy socio-economic cost associated with them.

The Papineau technique remains the reference method for treating infected fractures in Mbujimayi [13]. It consists of first healing the soft tissue lesions (wound healing) using conventional antiseptic solutions (physiological saline, Dakin, flammazine, etc.), then performing definitive bone treatment using the Papineau technique. During the time of soft tissue treatment, the limb remains temporarily immobilized either in a metal splint or by transosseous traction. This method of delayed bone treatment is not satisfactory, given its poor therapeutic results in terms of time to achieve satisfactory bone consolidation and patient inactivity.

## Possible alternative solution

We asked ourselves the following question: would the use of natural honey associated with the Papineau technique as first-line treatment improve the post-operative evolution of open leg bones fractures assessed Gustilo 2 and 3 by reducing the hospital stay of patients in the hospitals of Mbujimayi compared to the classic Papineau method?

The choice of honey was motivated by its effectiveness in the treatment of wounds, which significantly reduces healing time and bacterial load, as has been proven in several studies,

including one conducted in Mbujimayi on a sample of 105 patients, of whom the 54 who had been treated with honey saw the average healing time of their wounds reduced by half (23 days) compared to the group treated with standard antiseptics [14,15]. Honey would also accelerate the process of bone consolidation thanks to its composition which is rich in carbohydrate, proteins, vitamins and mineral salts [16,17].

The general objective of this study was to provide evidence of the benefit of treating severe open fractures of the leg bones using the Papineau technique as a first-line treatment combined with natural honey, in a resource-limited setting such as the city of Mbujimayi.

**Methods**

Study design and setting: This quasi-experimental study was carried out in the surgical departments of three hospitals in the city of Mbujimayi (University Clinics of Mbujimayi, Bonzola General Hospital and Muya General Hospital), Democratic Republic of Congo; from January 1, 2017 to March 30, 2025, i.e., over a period of 8 years and 3 months.

Population and sample of the study: It covered patients with open fractures of the leg bones treated in the aforementioned departments. Our sample was of simple random type, consisting of 91 patients divided into three groups according to the treatment method used:

a. The first group (control group), that of patients treated by the ordinary Papineau method, had initially undergone conservative treatment, that is to say, upon admission, an attempt was made to heal the wound using conventional antiseptics. During the time of soft tissue management, the limb remained temporarily immobilized either in a metal gutter, or in a cruro-pedal plaster splint, or by transosseous traction. The intervention was then performed when an unfavorable evolution was noted (superficial or deep infection). The Papineau technique performed here remained the same as that described in the literature[13]:

- Bone excision and excision of all infected soft tissue, the cavity is filled with compresses soaked in flammazine ointment or with tulle gras compresses; the dressing is left in place for two weeks;
- Final filling of the cavity with cancellous bone grafts followed by daily rinsing for two hours with one litre of physiological solution until the grafts are covered by granulation tissue (approximately 3 weeks);
- Spontaneous skin healing or more often by skin graft.

b. The second group consisted of patients operated on using the Papineau method described above, but as a first-line treatment, without undergoing conservative treatment.

c. The third group was that of patients operated on first by the modified Papineau method. In this method of ours,the filling of the bone cavity excised during the first stage was done with the honey-based compress sausage unlike the sausage soaked in flammazine made in the classic Papineau.

The data was collected using an anonymous form encoded on the KoboCollect application, from thepatient medical records, consultation and hospitalization records as well as surgical reports.

The independent variables retained were: socio-demographic (sex and age),clinear(time between admission and initial treatment, time between initial treatment and final treatment,fracture type according to the Gustilo and Anderson classification, time to infection, type of infection) and therapeutic (dressing frequency, antiseptic used for dressingAndtreatment method).

The dependent variables were: healing time, sufficient consolidation time, length of hospital stay, total length of treatment, length of time allowed for partial and total weight bearing, and length of time taken to resume activities since the injury.

The data collected and stored on the KoboCollect server were uploaded to an Excel spreadsheet and analyzed using IBM SPSS Advanced Statistics 2.0.0 software.

The results obtained were presented in the form of tables and expressed using numbers (n) with proportions (%) and means (M) with standard deviation (SD). Chi-square test and correlation test were also used. Comparison of means was made using one-way ANOVA test, supplemented by Tukey's post-hoc test.HSD. Links were considered significant when the p-value was $\leq 0.05$.

The honey used in this study was previously tested in approved laboratories in our country. It was proven sterile (after analysis in the bacteriology laboratory of the Clinic of the Mining Company of Bakwanga) and its physico-biochemical properties (useful for wound healing and bone remineralization) were determined by biochemical analysis at the Agro-Food Research Center of Lubumbashi (CRAA). Its conservation and packaging were carried out under the required conditions.

**Ethics Approval Statement**

Our study received approval from the ethics committee of the Official University of Mbujimayi.(letter Ref/N: CUM/NTN/N°123/2024)It was conducted in accordance with the ethical principles governing biomedical studies involving humans, as stipulated in the Declaration of Helsinki, adopted at the 75th General Assembly of the World Medical Association (WMA) in October 2024 [36].**Results**

1. Sociodemographic characteristics of patients (sex and age).

In our series, the male sex was the most represented with 61/91 cases (67.0%). The sex ratio was 2.0. The age group from 20 to 39 years was the most affected with 43/91 cases (47.3%). The mean age was 36.0 ± 13.0 years with extremes of 17 and 68 years

2. Clinical data of the lesions

More than half of the patients (47/91 cases, 51.6%) with open fractures of the leg bones received first aid more than six hours after admission. Open Gustilo type 2 fractures were the majority with 53/91 cases (58.2%). Patients without other comorbidities were the most numerous (64/91 cases, 70.3%) (Table 1).

Table 1. Time from admission to first aid , severity of injuries and comorbidity.

| Characteristics of the lesions | Therapeutic act | | | Total | Chi-square | p-value |
|---|---|---|---|---|---|---|
| | Ordinary Papineau (n=31) | Papineau in PI without honey (n=28) | Papineau in PI + Honey (n=32) | | | |
| Time from admission to first aid | | | | | 7,801 | 0.124 |
| ≤ 6 hours | 11 (35.5) | 8 (28.6) | 25 (78.1) | 44 | | |
| > 6 hours | 20 (64.5) | 20 (71.4) | 7 (21.9) | 47 | | |
| Severity of injuries | | | | | 1,137 | 0.888 |
| Gustilo 2 | 18 (58.1) | 16 (57.1) | 19 (59.4) | 53 | | |
| Gustilo 3a | 5 (16.1) | 5 (17.9) | 3 (9.4) | 13 | | |
| Gustilo 3b | 8 (28.8) | 7 (25.0) | 10 (31.2) | 25 | | |
| Comorbidity | | | | | 10,760 | 0.377 |
| Absent | 21 (67.7) | 20 (71.4) | 23 (71.9) | 64 | | |
| Presents | 10 (32.3) | 8 (28.6) | 9 (28.1) | 27 | | |

Comorbidity present = presence of associated pathologies such as high blood pressure, diabetes mellitus, asthma and malnutrition.

The majority of patients (53/91 cases, 58.2%) had received definitive bone treatment beyond 72 hours. Infection was present upon admission in a large proportion of our patients (61/91 cases, 69.2%) and was deep in 49/91 cases (53.8%) (Table 2).

Table 2. Time from first aid to final treatment, type of infection and time to onset of this infection.

| Characteristics of the lesions | Therapeutic act | | | Total | Chi-square | p-value |
|---|---|---|---|---|---|---|
| | Ordinary Papineau (n=31) | Papineau in PI without honey (n=28) | Papineau in PI + Honey (n=32) | | | |
| Time from first aid to final treatment (hours) | | | | | 4,211 | 0.300 |
| ≤ 24 | 0 (0.0) | 13 (46.4) | 16 (50.0) | 29 | | |
| 25 – 72 | 0 (0.0) | 5 (17.9) | 4 (12.5) | 9 | | |
| > 72 | 31 (100.0) | 10 (35.7) | 12 (37.5) | 53 | | |
| Type of infection | | | | | 3,403 | 0.101 |
| Deep infection | 22 (71.0) | 18 (64.3) | 9 (71.9) | 49 | | |
| Superficial infection | 9 (29.0) | 10 (35.7) | 23 (28.1) | 42 | | |
| Time to onset of infection after initial treatment (in hours) | | | | | 3,338 | 0.138 |
| Infection on admission | 21 (67.7) | 18 (64.3) | 22 (68.8) | 61 | | |
| ≤ 72 hours post-first aid | 2 (6.5) | 9 (32.1) | 8 (25.0) | 19 | | |
| > 72 hours after first treatment | 8 (25.8) | 1 (3.6) | 2 (6.2) | 11 | | |

3. Evolution of patients treated by the three methods (ordinary Papineau, first-line Papineau without honey and first-line Papineau with honey).

After verifying the complete similarity between the three groups of patients, we compared the therapeutic results obtained in the three groups, each according to its therapeutic technique. These results are presented here.

The Papineau technique as a first-line treatment with honey significantly reduced the various average delays studied (Wound healing time, time to partial or total weight-bearing, length of hospital stay, time to sufficient consolidation, time to return to activities and total duration of total care), compared to the other two methods (p=0.000) (Table 3).

Table 3. Wound healing time, time to partial or total weight-bearing, length of hospital stay, time to sufficient consolidation, time to return to activities and total duration of total care (one-way ANOVA test).

| | **Therapeutic act** | | | Total | ANOVA test (F-value) | p-value |
|---|---|---|---|---|---|---|
| **Evolution** | Ordinary Papineau (n=31) Mean ± SD | Papineau in PI without honey (n=28) Mean ± SD | Papineau in PI + Honey (n=32) Mean ± SD | | | |
| Healing time (days) | 72.2 ± 9.5 | 62.5 ± 13.1 | 46.8 ± 11.1 | 60.3 ± 15.4 | 40.75 | 0.000 |
| Partial support period (weeks) | 13.2 ± 1.8 | 12.1 ± 1.3 | 9.6 ± 1.9 | 11.7 ± 2.3 | 34.05 | 0.000 |
| Total support time (weeks) | 23.8 ± 2.5 | 23.6 ± 3.8 | 18.4 ± 3.0 | 21.8 ± 4.0 | 30.46 | 0.000 |
| Length of hospital stay (months) | 8.3 ± 1.0 | 6.9 ± 1.3 | 5.5 ± 1.7 | 6.9 ± 1.8 | 31.56 | 0.000 |
| Consolidation period (months) | 11.6 ± 1.1 | 9.3 ± 0.8 | 7.7 ± 1.0 | 9.2 ± 1.6 | 70.89 | 0.000 |
| Deadline for resumption of activities (months) | 12.6 ± 1.0 | 10.0 ± 1.3 | 8.8 ± 1.2 | 9.8 ± 1.4 | 21.02 | 0.000 |
| Total coverage period (months) | 12.7 ± 1.1 | 10.2 ± 1.3 | 8.8 ± 1.2 | 10.0 ± 1.5 | 26.14 | 0.000 |

4. Post-hoc comparisons (Tukey HSD test)
   Tables 4 and 5 below present the comparisons between our three treatment methods using the Tukey HSD post-hoc test, covering several variables related to patient outcomes (healing time, partial and total weight-bearing times, time to sufficient consolidation, time to return to activities, length of hospital stay, and total length of care):

1. Healing time (days):

   - The results show that protocol 3 (Papineau in PI with honey) significantly reduces the healing time compared to protocols 1 (ordinary Papineau) and 2 (Papineau in PI without honey).

- The difference is particularly marked with a shorter average of 25 days between groups 1 and 3 (p=0.000) (Table 4).

2. Total support time (weeks):
   - A significant reduction in the time to total support was observed in the group of patients treated with protocol 3, with a mean difference of more than 5 weeks compared to the groups treated with protocols 1 and 2 (p=0.000).
   - Groups 1 and 2 do not show any significant difference (p=0.990) (Table 4).
3. Partial support delay (weeks):
   - Protocol 3 shows a significant decrease in partial support time compared to groups treated with protocols 1 and 2.
   - The difference with group 2 reached 2.54 weeks (p=0.000) (Table 4).
4. Consolidation period (months):
   - The results confirm a significant improvement in the time to sufficient consolidation in the group treated with protocol 3, with a reduction of 2.93 months compared to group 1 (p=0.000) and 1.59 months compared to group 2 (p=0.000) (Table 4).
5. Deadline for resumption of activities (months ):
   - Group 3 showed a significantly faster time to return to activities compared to groups 1 and 2 (p=0.000p).
   - As for groups 1 and 2, they do not present any significant difference (p=0.058) (Table 5).
6. Length of hospital stay (months):
   - The results indicate a significant reduction in hospital stay time for group 3 compared to groups 1 and 2 (p=0.000).
   - A significant difference is also observed between groups 1 and 2 (p=0.001) (Table 5).
7. Total coverage period (months):
   - Group 3 showed a significantly reduced total duration of care (p=0.000), with marked differences compared to groups 1 and 2.

   - Groups 1 and 2 show a marginal but significant difference (p=0.042) (Table 5).

Table 4. Post-hoc comparisons (Tukey HSD test): Wound healing, partial or total weight-bearing and consolidation times.

| Dependent variable | | (I) Action taken | (J) Action taken | Mean difference (MI) | AND | p-value. | CI (95%) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Low | Raised |
| Healing time (days) | Tukey HSD | 1 | 2 | 9,697 | 2,933 | 0.004 | 2.71 | 16.69 |
| | | | 3 | 25,349 | 2,835 | 0.000 | 18.59 | 32.11 |
| | | 2 | 1 | -9,697 | 2,933 | 0.004 | -16.69 | -2.71 |
| | | | 3 | 15,652 | 2,911 | 0.000 | 8.71 | 22.59 |
| | | 3 | 1 | -25,349 | 2,835 | 0.000 | -32.11 | -18.59 |
| | | | 2 | -15,652 | 2,911 | 0.000 | -22.59 | -8.71 |
| Total support time (weeks) | Tukey HSD | 1 | 2 | 0.106 | 0.804 | 0.990 | -1.81 | 2.02 |
| | | | 3 | 5,334 | 0.777 | 0.000 | 3.48 | 7.19 |
| | | 2 | 1 | -0.106 | 0.804 | 0.990 | -2.02 | 1.81 |
| | | | 3 | 5,228 | 0.798 | 0.000 | 3.33 | 7.13 |
| | | 3 | 1 | -5,334 | 0.777 | 0.000 | -7.19 | -3.48 |
| | | | 2 | -5,228 | 0.798 | 0.000 | -7.13 | -3.33 |
| Partial support delay (weeks) | Tukey HSD | 1 | 2 | 1.0585 | 0.464 | 0.064 | -0.047 | 2,164 |
| | | | 3 | 3,5996 | 0.448 | 0.000 | 2,531 | 4,668 |
| | | 2 | 1 | -1.0585 | 0.464 | 0.064 | -2,164 | 0.047 |
| | | | 3 | 2,5411 | 0.460 | 0.000 | 1,444 | 3,638 |
| | | 3 | 1 | -3,5996 | 0.448 | 0.000 | -4,668 | -2,531 |
| | | | 2 | -2.5411 | 0.460 | 0.000 | -3,638 | -1,444 |
| Consolidation period (months) | Tukey HSD | 1 | 2 | 1,327 | 0.255 | 0.000 | 0.72 | 1.93 |
| | | | 3 | 2,925 | 0.246 | 0.000 | 2.34 | 3.51 |
| | | 2 | 1 | -1,327 | 0.255 | 0.000 | -1.93 | -0.72 |
| | | | 3 | 1,598 | 0.253 | 0.000 | 1.00 | 2.20 |
| | | 3 | 1 | -2,925 | 0.246 | 0.000 | -3.51 | -2.34 |
| | | | 2 | -1,598 | 0.253 | 0.000 | -2.20 | -1.00 |

Action taken: 1 (ordinary Papineau), 2 (Papineau in PI without honey) and 3 (Papineau in PI with honey). CI (Confidence interval).

Table 5. Post-hoc comparison (Tukey HSD test): Time to return to activities, length of hospital stay and total length of care.

| Dependent variable | | (I) Action taken | (J) Action taken | Mean difference (MI) | AND | p-value. | CI (95%) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Low | Raised |
| Time to resume activities (months) | Tukey HSD | 1 | 2 | 0.710 | 0.306 | 0.058 | -0.02 | 1.44 |
| | | | 3 | 1,897 | 0.296 | 0.000 | 1.19 | 2.60 |
| | | 2 | 1 | -0.710 | 0.306 | 0.058 | -1.44 | 0.02 |
| | | | 3 | 1,188 | 0.304 | 0.001 | 0.46 | 1.91 |
| | | 3 | 1 | -1,897 | 0.296 | 0.000 | -2.60 | -1.19 |
| | | | 2 | -1,188 | 0.304 | 0.001 | -1.91 | -0.46 |
| Length of hospital stay (months) | Tukey HSD | 1 | 2 | 1,397 | 0.359 | 0.001 | 0.54 | 2.25 |
| | | | 3 | 2,759 | 0.347 | 0.000 | 1.93 | 3.59 |
| | | 2 | 1 | -1,397 | 0.359 | 0.001 | -2.25 | -0.54 |
| | | | 3 | 1,362 | 0.357 | 0.001 | 0.51 | 2.21 |
| | | 3 | 1 | -2,759 | 0.347 | 0.000 | -3.59 | -1.93 |
| | | | 2 | -1,362 | 0.357 | 0.001 | -2.21 | -0.51 |
| Total duration of support (months) | Tukey HSD | 1 | 2 | 0.757 | 0.308 | 0.042 | 0.02 | 1.49 |
| | | | 3 | 2,123 | 0.298 | 0.000 | 1.41 | 2.83 |
| | | 2 | 1 | -0.757 | 0.308 | 0.042 | -1.49 | -0.02 |
| | | | 3 | 1,366 | 0.306 | 0.000 | 0.64 | 2.09 |
| | | 3 | 1 | -2,123 | 0.298 | 0.000 | -2.83 | -1.41 |
| | | | 2 | -1,366 | 0.306 | 0.000 | -2.09 | -0.64 |

Action taken: 1 (ordinary Papineau), 2 (Papineau in PI without honey) and 3 (Papineau in PI with honey). CI (Confidence interval).

**Discussion**

1. Sociodemographic characteristics of patients (sex and age).

In our series, the male sex was the most represented with 61/91 cases (67.0%) and a sex ratio of 2.0. The age group from 20 to 39 years was the most affected with 43/91 cases (47.3%) and the average age of patients was 36.0 ± 13.0 years with extremes of 17 and 68 years. Our results are similar with many data from the literature [18,19, 20]. Layes et al in Mali in 2020 found 18 men and 12 women with an average age of 34.4 years with extremes of 10 to 50 years [21]. The link between trauma, male sex and young age is no longer to be demonstrated to date, as reported in a recent study conducted inMbujimayi [15].

2. Clinical data of the lesions

Our work specifies that more than half of the patients (47/91 cases, 51.6%) with open fracture of the leg bones received first aid more than six hours after admission. Laigle M et al. also reported in their study that the time between the occurrence of trauma and the start of first aid (surgical debridement, in this case) was more than 6 hours [22]. This observation reveals the

flaws of our system, which does not have a network for collecting the injured, as well as health coverage accessible to all social classes.

Open fractures of Gustilo type 2 were the majority with 53/91 cases (58.2%). The series ofEnweluzo et al supports ours by indicating a similar trend [23].While forTouré et al, type 1 and 2 open fractures were the most frequent [24]. This distribution was also noted in the series of Camara et al [25].

Several patients (53/91 cases, 58.2%) had received definitive bone treatment beyond 72 hours. According to Layes et al, in 50% of cases in their series, osteosynthesis was performed between the 7th and 12th hour, whereas in the study by Ghosh S et al, patients were treated between the 2nd and 3rd week following the trauma [26]. This delay in treatment is corollary to that with which patients consult in the trauma-orthopedic surgery department in Mbujimayi, where conventional medicine is often considered as a second resort after the failure of self-medication and therapies initiated by traditional practitioners.

This finding corroborates the increased frequency of infections in our series where 61/91 cases (69.2%) were admitted with the infection, which was deep in 49/91 cases (53.8%).Our results confirm the observation of Kikobya S according to which the delay greater than 24 hours separating the occurrence of fracture and arrival at the place of care would expose five times more to the risk of infection [27].

3. Evolution of patients treated by the three methods (ordinary Papineau, first-line Papineau without honey and first-line Papineau with honey).

In our series, we had the privilege of conducting a study that compared three methods of managing infected open fractures of the leg bones in Mbujimayi.

Our research has allowed us to observe that the Papineau technique carried out as a first-line treatment combined with honey significantly reduces the various average times studied (wound healing time, time to partial or total weight bearing, length of hospital stay, time to sufficient consolidation, time to return to activities and total duration of total care), compared to the two other methods: ordinary Papineau and Papineau 1st intention without honey (p=0.000):

a. The mean healing time was 46.8 ± 11.1 for Papineau in first intention with honey, compared to the others with respectively 62.5 ± 13.1 (Papineau in first intention without honey) and 72.2 ± 9.5 (ordinary Papineau). In the series of Kevin et al, the mean healing time was 24.56 days (range 18 to 57 days) [20]. This discordance between the different series could be explained by the wide variety of methods used to achieve healing; some preferring to immediately perform a skin suture or a myocutaneous flap graft [28,29] and others, like us, favoring directed healing.
   The reduced duration ofhealingobserved when using honeyin our study,would be explainedby the biochemical composition of honey including the hydrogen peroxide it contains and which intervenes in the healing phenomenon by stimulating thethe proliferation ofkeratinocytes and allows the renewal of the endothelium [30].
b. In our series, partial weight bearing was allowed on average, respectively at 9.6 ± 1.9 weeks (2.5 months) for the first-line Papineau method with honey, at 12.1 ± 1.3 weeks for the

first-line Papineau method without honey and at 13.2 ± 1.8 weeks for the ordinary Papineau method. As for total weight bearing, it was allowed at 18.4 ± 3.0 weeks (4 to 4.5 months) for the method with honey and at 23.6 ± 3.8 and 23.8 ± 2.5 weeks respectively for the other methods. According to Said et al [18] in their series, partial weight bearing was allowed on average at the third month (12 weeks) and totaled at the fourth while that ofOmar et al reported an average partial support delay at the 3rd week, total on average at the 90th day (3 months) [19]. The authorizationThe early partial and total support in Omar's research could be explained by the fact that the osteosynthesis of his patients had been done by locked nailing (recent open fractures of type 1 and 2) for the majority of cases.

According to literature l'supportprogressive is allowed between 6th and 8thsemaine during a simple fracture, 8th and 12thweek if the fracture is complex while full weight bearing is generally permitted between the 14$^{th}$and 16$^{th}$week [31].

c. The average length of hospitalization in our series was 5.5 ± 1.7 months for honey and for the other methods respectively 6.9 ± 1.3 months and 8.3 ± 1.0. For Kevin et al, it was 17.68 days (range 11 to 38 days) [20]. For Bénié et al, the average length of hospitalization was 14.1 ± 21.2 days (range 1 to 150 days) [32]; while it increases even more in the series of Monka et al. (24 to 330 days) [33].

   It is clear that the length of hospitalization, which depends on several parameters including the severity of injuries, patient comorbidities, the presence of infection at the fracture site, and the therapeutic methods used, is highly variable in the literature and depends on one study to another. The long hospitalization period reported in our study could be justified by the fact that we treated patients with infected open fractures, who were operated on in two stages. However, compared to the conventional method, the hospital stay of patients was significantly shortened thanks to our method of management.

d. The mean time to sufficient consolidation in our study was 7.7 ± 1.0 months in patients treated by our method, while it was 9.3 ± 0.8 months and 11.6 ± 1.1 months respectively for the other two methods, results which are similar to thoseof Said [18]. In the series of Layes et al, consolidation was obtained on average between 5 and 14 months [21]. The method tested in this study demonstrated a reduced consolidation time compared to other methods used locally.

   This rapid consolidation observed with our method of support would belinked totherapeutic properties of honeywhich stimulates proliferationration of connective tissues (fibroblasts) whose predominant role in the constitution of bone callus is known [15,34,35].

e. In our series, as in others, the average time to return to activities and that of overall care are readily confused. These times were respectively, in our case, 9.8 ± 1.2 months for our method under study, 10.2 ± 1.3 and 12.7 ± 1.1 months for the other methods. Results which remain within the limits of those reported in the literature, notably by Bénié et al (10.2 ± 3.9 months) or Kevin et al (13.8 months) [20,32].

**Conclusion and perspectives**

Ultimately, the data from this study demonstrate that the use of honey as a complement to the Papineau technique as a first-line treatment has a positive impact on therapeutic results. Indeed, the experimental protocol used in this study, combining the Papineau technique as a first-line treatment with honey, significantly showed much better post-operative results than those obtained with the dtwo other methods studied. This observation is objectively reflected by the significant reduction in the following indicators: the dwound healing time, time to partial or total weight bearing, length of hospital stay, time to achieve sufficient bone consolidation, time to resume activities after the trauma and the total duration of patient care. These figures are a strong argument to justify its adoption in the treatment of open fractures of the Gustilo 2 and 3 leg bones in our environment to improve clinical results and significantly reduce the high socio-professional and economic cost, related to long periods of unavailability of subjects admitted to the bone surgery departments of Mbujimayi hospitals.

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