

Hoffmann osteotaxis for tibial fractures: soft-tissue complications, infection and union in a historical Belgian cohort

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ABSTRACT

Hoffmann osteotaxis is part of Belgian tibial fracture history. We describe an archival multicentre cohort and examine associations between soft-tissue category, secondary skin necrosis, historically recorded local infection and union outcomes. Aggregate tables from a publicly deposited 1980 Université libre de Bruxelles memoir were transcribed and checked against source totals. The unit of analysis was the fracture. The cohort included 1,147 fresh, initially non-infected tibial fractures treated with Hoffmann external fixation in seven collaborating centres: 890 men and 257 women. Secondary skin necrosis occurred in 164 fractures and recorded local infection in 44. Named historical open-fracture categories showed higher skin-necrosis and infection rates than closed fractures without contusion. Final source-defined outcomes were consolidation in 882 fractures, temporary pseudarthrosis in 38, definitive pseudarthrosis in 100 and unknown in 127. This archive is a historical benchmark, not comparative evidence for current fixation choices.

Keywords: Tibial fractures, Hoffmann external fixation, osteotaxis, soft-tissue complications, infection, pseudarthrosis, historical cohort.

INTRODUCTION

External fixation has had a central role in the historical development of tibial fracture care because it can stabilise bone while limiting further surgical injury to compromised soft tissues. Hoffmann modular fixation was particularly influential in continental Europe and was closely associated in Belgium with osteotaxis, indirect reduction, percutaneous fixation, preservation of fracture biology and functional loading as healing advanced¹.

This archive extends earlier Belgian reports published in *Acta Orthopaedica Belgica*, including clinical studies of tibial fractures treated by osteotaxis^{2,3}, strain-gauge monitoring of fracture consolidation⁴, biomechanical studies of the Hoffmann fixator⁵, and complications associated with osteotaxis⁶. The value of the present reanalysis is historical and methodological. It does not test Hoffmann osteotaxis against contemporary locked intramedullary nailing, nor does it propose external fixation as routine definitive care for modern tibial fractures.

The aims were to describe the provenance of a 1980 Université libre de Bruxelles source archive, report the main characteristics and outcomes of 1,147

fresh, initially non-infected tibial fractures treated by Hoffmann osteotaxis, and examine unadjusted associations between historical soft-tissue categories, secondary skin necrosis, historically recorded local infection and source-defined pseudarthrosis. The study is presented as an archival benchmark rather than newly collected clinical evidence.

MATERIALS AND METHODS

Study design and source archive

This is a historical archival reanalysis of aggregate tables from the 1980 institutional surgical memoir by Sabri El Banna, entitled *Fractures diaphysaires du tibia: résultat du traitement par fixateur externe d'Hoffmann*.¹ The memoir has a stable public record in the ULB DI-fusion repository. The memoir itself described a multicentre collection of more than 1,400 fractures of the leg or tibia treated by Hoffmann osteotaxis and selected 1,147 fresh, initially non-infected fractures for the general clinical analysis.

The source acknowledgement identified collaborating services and surgeons from Montignies-sur-Sambre, Anderlecht, Brussels, Barcelona, Algiers and Bordeaux, with the ULB/Erasmé environment

forming the institutional base of the memoir. Centre-specific recruitment periods, centre-level denominators and centre-specific treatment protocols are not reconstructable from the aggregate source tables currently available.

Relationship to previous *Acta Orthopaedica Belgica* material

The present article is related to, but broader than, the 1979 *Acta Orthopaedica Belgica* article on simple tibial fractures treated by osteotaxis³. That article is treated as a related historical report, not as an independent validation cohort. The 1980 memoir contains a 450-fracture simple subset selected from the 1,147-fracture archive, whereas the 1979 article is cited with a different simple-fracture count in secondary bibliographic discussions. Because patient-level identifiers are unavailable, exact numerical overlap cannot be reconstructed. The 450-fracture subset is therefore used only as contextual material and is not the primary analytical cohort.

The present manuscript does not present the archive as newly collected evidence. It reports a transparent reanalysis of aggregate historical tables, with a supplementary concordance table identifying the source tables from which the present variables were transcribed or recombined (Supplementary Table I).

Data extraction and verification

Aggregate data were transcribed from the digitised memoir and checked against the printed row totals, column totals and denominators in the source tables. The primary denominator of 1,147 fractures was retained only when the source table itself used that denominator. Variable-specific missing or unknown categories were retained rather than deleted. The extraction was not performed as a blinded dual-review process, which is a limitation of this historical reanalysis; however, every table in the manuscript is traceable to a source table or source cross-tabulation.

The unit of analysis was the fracture. The source protocol did not allow determination of whether any patient contributed bilateral or multiple fractures. Potential non-independence of observations is therefore acknowledged and no patient-level inference is attempted.

Definitions

Historical terminology was retained. The source used French-language Cauchoix-era categories for open tibial fractures^{7,8}. The terms type I, type II and type III are therefore reported as historical Cauchoix-type

open-fracture categories and are not converted into modern Gustilo-Anderson grades⁹.

The registry term sepsis is reported as recorded sepsis or recorded local infection. It denotes a clinician-recorded infectious complication in the historical archive and should not be equated with systemic sepsis or with contemporary consensus-defined fracture-related infection^{10,11}.

Secondary skin necrosis was treated as a post-injury soft-tissue complication, distinct from the initial open-fracture category. Source-defined union outcomes were reported using the archive's own terms: final consolidation, temporary pseudarthrosis, definitive pseudarthrosis and unknown final outcome. The source protocol coded non-consolidation after the fixator as no pseudarthrosis, temporary pseudarthrosis evolving toward healing, definitive pseudarthrosis persisting after a 999-day delay, temporary pseudarthrosis requiring orthopaedic treatment, temporary pseudarthrosis requiring surgical treatment, or other. Accordingly, temporary pseudarthrosis was not renamed delayed union, and definitive pseudarthrosis was not automatically equated with modern nonunion.

Statistical analysis

Analyses were descriptive and unadjusted. The prespecified aggregate comparisons were: soft-tissue category versus secondary skin necrosis; soft-tissue category versus recorded local infection; reduction method versus recorded local infection; and soft-tissue category versus source-defined pseudarthrosis. Closed fracture without contusion was the reference category for soft-tissue comparisons, and closed reduction was the reference category for reduction-method comparisons.

Risk ratios, odds ratios and 95% confidence intervals were recalculated from the aggregate 2×2 tables. Katz log confidence intervals were used for risk ratios and Woolf logit confidence intervals for odds ratios. Zero-event cells were not estimated and are reported as not estimable. Pearson chi-square tests from the source were retained descriptively when available; no continuity correction was applied. Calculations were performed with Python 3.13. Because patient-level covariates were unavailable, no adjusted analysis, survival analysis or causal inference was attempted.

Ethics and data availability

The study used only aggregate, de-identified historical data extracted from a publicly accessible ULB institutional thesis. No individual patient

charts, names, dates of birth or other identifiers were accessed.

The source memoir is publicly available through ULB DI-fusion. The extracted aggregate dataset and calculation files can be supplied to the journal as supplementary material or to readers on reasonable request, subject to institutional authorization.

RESULTS

Cohort composition

The main historical cohort included 1,147 fresh, initially non-infected tibial fractures treated by Hoffmann osteotaxis. Men accounted for 890 fractures or cases (77.6%) and women for 257 (22.4%). The largest age group was 21–40 years (480/1,147; 41.9%). Mid-diaphyseal fractures were the most frequent recorded location (589/1,147; 51.3%).

The source archive recorded a broad soft-tissue spectrum: 321 closed fractures without contusion, 283 closed fractures without further precision, 40 closed fractures with contusion, 234 historical Cauchoux-type I open fractures, 114 type II open fractures, 110

type III open fractures, 35 open fractures without further precision, four other cutaneous lesions and six unknown entries. The complete source distribution is shown in Table I.

Treatment course, alignment and source-defined union

Treatment course, alignment and source-defined final outcomes are summarised in Table II.

Closed reduction was recorded in 753 fractures (65.6%), open reduction in 319 (27.8%) and minimally open reduction in 62 (5.4%); 13 fractures had other or unknown reduction categories. The fixator was retained until consolidation in 682 fractures (59.5%) and replaced by a cast in 267 (23.3%). Alignment was recorded as $<10^\circ$ in 1,009 fractures (88.0%), 10 degrees in 50 (4.4%), $>10^\circ$ in 29 (2.5%) and unknown in 59 (5.1%).

Final source-defined outcomes were mutually exclusive in the memoir's final-outcome table: final consolidation in 882 fractures (76.9%), temporary pseudarthrosis in 38 (3.3%), definitive pseudarthrosis in 100 (8.7%) and unknown final outcome in 127 (11.1%). The source also contained a separate

Table I. — Provenance, demographics and selected baseline characteristics of the 1,147-fracture archive.

Variable	Value	Source/handling
Source archive	>1,400 tibial fractures treated by Hoffmann osteotaxis	1980 memoir, clinical study introduction
Main analytical cohort	1,147 fresh, initially non-infected fractures	Primary denominator
Contextual simple subset	450 selected simple fractures	Context only, not primary analysis
Male sex	890/1,147 (77.6%)	Transcribed
Female sex	257/1,147 (22.4%)	Transcribed
Age 0–20 years	185/1,147 (16.1%)	Transcribed
Age 21–40 years	480/1,147 (41.9%)	Transcribed
Age 41–60 years	315/1,147 (27.5%)	Transcribed
Age 61–80 years	141/1,147 (12.3%)	Transcribed
Age 81–100 years	21/1,147 (1.8%)	Transcribed
Age unknown	5/1,147 (0.4%)	Transcribed
Middle diaphyseal location	589/1,147 (51.3%)	Most frequent level
Distal diaphyseal location	315/1,147 (27.5%)	Transcribed
Closed fracture without contusion	321/1,147 (28.0%)	Reference for soft-tissue analyses
Closed fracture without further precision	283/1,147 (24.7%)	Reported separately in source baseline table
Closed fracture with contusion	40/1,147 (3.5%)	Named soft-tissue stratum
Historical Cauchoux-type I open fracture	234/1,147 (20.4%)	Not modern Gustilo-Anderson grade
Historical Cauchoux-type II open fracture	114/1,147 (9.9%)	Not modern Gustilo-Anderson grade
Historical Cauchoux-type III open fracture	110/1,147 (9.6%)	Not modern Gustilo-Anderson grade
Open fracture without further precision	35/1,147 (3.1%)	Reported separately in source baseline table
Other cutaneous lesion / unknown	4/1,147 (0.3%); 6/1,147 (0.5%)	Reported separately in source baseline table
Percentages use 1,147 as denominator unless otherwise stated. Historical open-fracture categories are reported as Cauchoux-type archive categories and are not converted into modern Gustilo-Anderson grades.		

Table II. — Treatment course, alignment and source-defined final outcomes.

Variable	Value	Comment
Closed reduction	753/1,147 (65.6%)	Reference category for reduction-method analysis
Open reduction	319/1,147 (27.8%)	Likely confounded by fracture complexity
Minimally open reduction	62/1,147 (5.4%)	Opening “à minima” in source terminology
Other / unknown reduction	2 other; 11 unknown	Retained in denominator
Fixator retained until consolidation	682/1,147 (59.5%)	Historical definitive external-fixation pathway
Fixator replaced by cast	267/1,147 (23.3%)	Historical staged immobilisation practice
Fixator replaced by nail / plate	14/1,147 (1.2%); 14/1,147 (1.2%)	Minority staged conversion
Alignment <10°	1,009/1,147 (88.0%)	Source category; angle measurement method not reconstructable
Alignment =10°	50/1,147 (4.4%)	Source category
Alignment >10°	29/1,147 (2.5%)	Source category
Alignment unknown	59/1,147 (5.1%)	Missing category
Final consolidation	882/1,147 (76.9%)	Mutually exclusive final outcome category
Temporary pseudarthrosis	38/1,147 (3.3%)	Archive-defined; not renamed delayed union
Definitive pseudarthrosis	100/1,147 (8.7%)	Archive-defined pseudarthrosis / nonunion term
Final outcome unknown	127/1,147 (11.1%)	Missing final outcome category

The final outcome categories sum to 1,147 and are treated as mutually exclusive archive-defined categories. The separate source delay-to-consolidation table had its own missing-data structure and is not combined with these final outcome categories.

grouped delay-to-consolidation table with 92 unknown observations. Because that table was archive-defined and cannot be algebraically reconciled with the mutually exclusive final-outcome table, it is not combined with the final outcome categories for statistical inference.

Secondary skin necrosis and recorded local infection

Secondary skin necrosis was recorded in 164 fractures (14.3%). The rate increased across named historical soft-tissue categories: 15/321 closed fractures without contusion (4.7%), 10/40 closed fractures with contusion (25.0%), 39/234 historical Cauchoux-type I open fractures (16.7%), 29/114 type II open fractures (25.4%) and 57/110 type III open fractures (51.8%) (Table III).

Recorded local infection was reported in 44 fractures (3.8%). It followed a similar descriptive gradient: 6/321 closed fractures without contusion (1.9%), 3/40 closed fractures with contusion (7.5%), 10/234 type I open fractures (4.3%), 7/114 type II open fractures (6.1%) and 12/110 type III open fractures (10.9%). Open reduction was also associated with more recorded local infection than closed reduction: 22/319 (6.9%) versus 19/753 (2.5%) (Table IV).

Source-defined pseudarthrosis

Source-defined pseudarthrosis, combining temporary and definitive pseudarthrosis as recorded in the source table, was reported in 138 fractures (12.0%). It was more frequent in open and more severe soft-tissue categories than in closed fractures without contusion:

Table III. — Secondary skin necrosis according to historical soft-tissue category.

Category	N	Events, n (%)	RR (95% CI)	OR (95% CI)
Closed fracture without contusion (reference)	321	15 (4.7%)	1.00	1.00
Closed fracture with contusion	40	10 (25.0%)	5.35 (2.58-11.10)	6.80 (2.81-16.45)
Historical Cauchoux-type I open	234	39 (16.7%)	3.57 (2.01-6.31)	4.08 (2.19-7.60)
Historical Cauchoux-type II open	114	29 (25.4%)	5.44 (3.03-9.78)	6.96 (3.57-13.58)
Historical Cauchoux-type III open	110	57 (51.8%)	11.09 (6.55-18.76)	21.94 (11.58-41.57)
Other	290	14 (4.8%)	1.03 (0.51-2.10)	1.03 (0.49-2.18)
Unknown	38	0 (0.0%)	NE	NE

RR, risk ratio; OR, odds ratio; CI, confidence interval; NE, not estimable. Other comprises residual source categories not individually named in the available cross-tabulation, principally closed fractures without further precision, open fractures without further precision and other cutaneous lesions. Unknown denotes entries explicitly coded as unknown in the corresponding source cross-tabulation. These categories are retained only to preserve the source denominator and are not interpreted clinically.

Table IV. — Recorded local infection according to soft-tissue category and reduction method.

Panel / category	N	Events, n (%)	RR (95% CI)	OR (95% CI)
A. Recorded local infection by soft-tissue category				
Closed fracture without contusion (reference)	321	6 (1.9%)	1.00	1.00
Closed fracture with contusion	40	3 (7.5%)	4.01 (1.04-15.42)	4.26 (1.02-17.74)
Historical Cauchoix-type I open	234	10 (4.3%)	2.29 (0.84-6.20)	2.34 (0.84-6.54)
Historical Cauchoix-type II open	114	7 (6.1%)	3.29 (1.13-9.57)	3.43 (1.13-10.45)
Historical Cauchoix-type III open	110	12 (10.9%)	5.84 (2.24-15.18)	6.43 (2.35-17.58)
Other	290	2 (0.7%)	0.37 (0.08-1.81)	0.36 (0.07-1.82)
Unknown	38	4 (10.5%)	5.63 (1.66-19.07)	6.18 (1.66-22.98)
B. Recorded local infection by reduction method				
Closed reduction (reference)	753	19 (2.5%)	1.00	1.00
Open reduction	319	22 (6.9%)	2.73 (1.50-4.98)	2.86 (1.53-5.36)
Minimally open reduction	62	2 (3.2%)	1.28 (0.30-5.36)	1.29 (0.29-5.66)
Unknown / other reduction	13	1 (7.7%)	3.05 (0.44-21.10)	3.22 (0.40-26.03)
The source term sepsis is reported here as recorded local infection. Analyses are crude and unadjusted; open reduction is likely confounded by indication and fracture complexity. Other and Unknown reduction categories are retained to preserve the full source denominator.				

17/321 (5.3%) in closed fractures without contusion, 32/234 (13.7%) in type I open fractures, 21/114 (18.4%) in type II open fractures and 21/110 (19.1%) in type III open fractures (Table V).

A direct recorded-infection versus pseudarthrosis cross-tabulation was available in the source only for the contextual 450-fracture simple subset. In that subset, pseudarthrosis was recorded in 5/13 fractures with recorded local infection and in 23/418 without recorded local infection, with 19 entries of unknown infection status. This subset finding is reported only as context because the present primary cohort is the broader 1,147-fracture archive.

DISCUSSION

Principal findings

This historical Belgian multicentre archive documents a large experience with Hoffmann osteotaxis for tibial fractures. Its principal value is not comparative

effectiveness. The archive demonstrates strong unadjusted associations between historical soft-tissue severity and recorded secondary skin necrosis or local infection, while the source-defined outcome data show higher pseudarthrosis rates in open and more severe soft-tissue categories. These descriptive findings reinforce the historical clinical importance of soft-tissue preservation and infection control.

The manuscript should be read as a transparent archival reanalysis. It cannot verify individual eligibility, duplicate fractures, follow-up completeness, centre-level differences or patient-level confounders. It therefore cannot establish causal determinants of union or provide evidence for current fixation choices.

Historical value and relationship to previous reports

The archive is valuable because it preserves a large Belgian osteotaxis experience and links it to earlier

Table V. — Source-defined pseudarthrosis according to historical soft-tissue category.

Category	N	Source-defined pseudarthrosis, n (%)	RR (95% CI)	OR (95% CI)
Closed fracture without contusion (reference)	321	17 (5.3%)	1.00	1.00
Closed fracture with contusion	40	5 (12.5%)	2.36 (0.92-6.05)	2.55 (0.89-7.35)
Historical Cauchoix-type I open	234	32 (13.7%)	2.58 (1.47-4.54)	2.83 (1.53-5.24)
Historical Cauchoix-type II open	114	21 (18.4%)	3.48 (1.90-6.36)	4.04 (2.05-7.97)
Historical Cauchoix-type III open	110	21 (19.1%)	3.60 (1.98-6.58)	4.22 (2.13-8.34)
Other	290	32 (11.0%)	2.08 (1.18-3.67)	2.22 (1.20-4.09)
Unknown	38	10 (26.3%)	4.97 (2.46-10.06)	6.39 (2.67-15.27)
Source-defined pseudarthrosis combines temporary and definitive pseudarthrosis as recorded in the 1980 source table. It should not be equated automatically with modern delayed union or consensus-defined nonunion. Other and Unknown are retained to preserve source denominators and are not interpreted clinically.				

Acta Orthopaedica Belgica reports by Burny and colleagues. The 1979 simple-fracture article and the 450-fracture simple subset in the 1980 memoir appear related, but patient-level overlap cannot be reconstructed from the available aggregate source. The present manuscript therefore focuses on the 1,147-fracture archive and treats the simple subset only as contextual historical material.

The evolution of Hoffmann fixation has been reviewed separately¹². Experimental work addressed controlled micromovement during fracture healing¹³, while reconstructive studies examined soft-tissue management in severe extremity injuries^{14,15}. This framing is deliberately narrower than a contemporary review of external fixation. A systematic overview and meta-analysis of open tibial shaft fractures found lower risks of reoperation, malunion and superficial infection with unreamed intramedullary nails than with external fixators¹⁶. The contemporary relevance of the archive is therefore important but limited: it illustrates the enduring biological relation between soft-tissue injury, secondary skin necrosis, recorded local infection and healing complications.

Terminology and interpretation

Terminology drift is a major risk when analysing historical fracture archives. The source used terms such as sepsis, temporary pseudarthrosis and definitive pseudarthrosis. These have been retained rather than silently translated into systemic sepsis, fracture-related infection, delayed union or modern nonunion. This preserves historical fidelity and prevents overinterpretation.

The residual cross-tabulation categories require caution. The baseline source table separates closed fractures without further precision, open fractures without further precision, other cutaneous lesions and unknown entries. In the available secondary cross-tabulations, residual strata were grouped as Other and Unknown. This grouping was retained for denominator preservation and was applied consistently across the descriptive analyses, but these residual categories are not interpreted clinically because patient-level mapping from the baseline table is not reconstructable.

Strengths and limitations

Strengths include the large sample size, multicentre origin, direct connection with the Belgian development of Hoffmann osteotaxis, use of exact historical denominators and explicit preservation of historical terminology. The addition of a source concordance table makes the reanalysis auditable.

Limitations are substantial. The analysis depends entirely on aggregate historical tables. Individual eligibility, duplicate fractures, bilateral injuries, diagnostic criteria, timing, follow-up completeness and confounding variables cannot be verified. Centre-level heterogeneity is likely: the collaborating services may have differed in patient selection, indications for external fixation, wound care, antibiotic practices, reduction thresholds, weight-bearing protocols and outcome ascertainment. Centre-specific denominators cannot be reconstructed from the available aggregate source tables.

CONCLUSION

The 1980 Hoffmann osteotaxis archive should be preserved as a historical Belgian multicentre benchmark. It documents strong descriptive associations between soft-tissue severity and secondary skin necrosis or historically recorded local infection, and it shows higher source-defined pseudarthrosis rates in open and more severe soft-tissue categories. The archive supports a durable but limited historical lesson: in tibial fracture care, soft-tissue preservation and infection control are closely associated with healing outcomes. It does not provide comparative evidence for current fixation choices.

Acknowledgements: Historical acknowledgement: the original 1980 source memoir acknowledged the interhospital collaboration that made the archive possible, including H. Evrard; M. Vander Ghinst; L. De Geeter; M. Peeters; M. Fernandez Fairen; Morera; Martini; Le Rebeller; Chauveaux; J. Van Geertruyden; R. de Marneffe; P. Smets; E. Coussaert; M. Donkerwolcke; and A. Dedry. This acknowledgement records historical contribution to the archive and does not imply current authorship responsibility.

Conflicts of interest: None declared.

Funding: None.

Data availability: The 1980 institutional memoir is publicly accessible through the ULB DI-fusion repository. The extracted aggregate dataset and calculation files can be supplied to the journal as supplementary material or to readers on reasonable request, subject to institutional authorization; they contain no patient identifiers.

Ethics and archival governance: This article reports only aggregate, de-identified historical data extracted from a publicly accessible ULB institutional thesis. No individual patient charts, names, dates of birth or other identifiers were accessed.

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Supplementary Table I. — Concordance between source archive and present manuscript.

Present variable or analysis	Source location in 1980 memoir	Use in present manuscript	Quality-control note
Archive size and selected cohort	Clinical study introduction	Provenance statement	Reported as >1,400 source fractures and 1,147 selected fresh, initially non-infected fractures
Sex and age	Tables 8-9	Table I	Row totals checked against 1,147
Fracture pattern and level	Tables 10-11	Baseline description / Table I	Selected major categories transcribed
Soft-tissue category	Table 12	Table I and reference categories	Baseline categories retained; cross-tab grouping limitations noted
Reduction method	Table 14	Table II and Table IVB	Row totals checked against 1,147
Fixator course	Table 16	Table II	Row totals checked against 1,147
Alignment	Table 17	Table II	Unknown alignment retained
Delay to consolidation	Table 18	Methods / Results limitation	Not combined with final outcome categories because definitions and missingness differ
Final outcome / pseudarthrosis	Table 28	Table II	Mutually exclusive source-defined final categories
Secondary skin necrosis	Tables 21-23	Table III	Events checked against total 164
Recorded local infection	Tables 24-26	Table IV	Events checked against total 44
Pseudarthrosis by soft-tissue category	Table 30	Table V	Events checked against total 138 temporary + definitive pseudarthroses
Simple-fracture subset	Tables 34-48 and related complication tables	Context only	Not used as primary cohort because overlap with 1979 article cannot be patient-level matched
The table is intended to make the archival reanalysis auditable. Patient-level verification, duplicate-patient assessment and centre-specific reconstruction were not possible from the aggregate source tables.			

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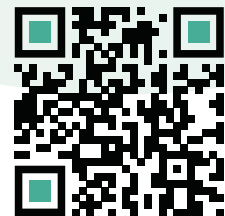
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