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RESEARCH ARTICLE

Management of Mandibular Fractures in Neonatal Calves with a Semicircular External Fixator: Clinical and Radiographic Outcomes

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ABSTRACT

This study aimed to evaluate the clinical and radiographic outcomes of semicircular external fixation technique combined with transmandibular Kirschner wire fixation in a crossed and linear configuration neonatal calves with dystocia-related mandibular fractures. Twenty neonatal calves with mandibular fractures caused by improper traction during obstetrical intervention were included. Clinical and radiographic examinations were performed, and fracture localization, unilateral or bilateral involvement, open or closed fracture configuration, fragment displacement, and oral functional impairment were recorded. Mandibular stabilization was achieved in all cases using 2-mm Kirschner wires placed in transmandibular cross-linear configuration combined with a semicircular external fixator ring. Postoperative follow-up included evaluation of clinical recovery, implant stability, complications, oral feeding ability, and radiographic bone healing. Radiographic assessments were performed on days 0, 21, 45, and 60-65 using a modified healing scoring system. Bilateral mandibular fractures were identified in 17 cases and unilateral fractures in 3 cases. No marked secondary displacement was observed during follow-up. Complete radiographic healing was documented in 16 calves, whereas two surviving calves showed moderate/incomplete healing by days 60–65. Two calves died before completion of follow-up due to pneumonia and were reported separately as pneumonia-related deaths. In conclusion, the semicircular external fixation configuration combined with transmandibular cross-linear Kirschner wire fixation appeared to be a clinically applicable and function-oriented option for selected neonatal mandibular fractures. However, comparative studies and biomechanical testing are required before superiority, cost-effectiveness, or mechanical advantages can be established.

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INTRODUCTION

Although mandibular fractures are relatively uncommon in adult cattle, they represent a considerable proportion of fracture cases encountered in calves (Aksoy *et al.*, 2009; Remala *et al.*, 2017). In neonatal calves, one of the primary causes of mandibular fractures is improper obstetrical manipulation and excessive traction applied to correct fetal head position during dystocia (Locher *et al.,* 2021, Kumar *et al.,* 2023, Canatan and Küken, 2026). Aksoy *et al.* (2009) reported mandibular fractures in 10 of 27 calves with traction-related fractures.

Mandibular fractures may also occur secondary to falls, collisions, and environmental trauma. In cattle, fractures are most commonly localized to the molar and diastema regions (Zimmermann *et al.*, 2022), whereas fractures involving the *symphysis mandibulae* are more prominent in calves (Yu *et al.*, 2020; Reddy *et al.*, 2024).

Clinical findings include ventral displacement of the rostral fragment, dental malalignment, tongue protrusion, excessive salivation, and intraoral or extraoral open fractures. These injuries may result in impaired suckling and feeding, milk or feed loss from the oral cavity, malocclusion, contamination, and infection, particularly in open fractures. Therefore, early diagnosis and appropriate surgical stabilization are essential (Remala *et al*., 2017).

Mandibular fractures can often be diagnosed by inspection and palpation; however, radiographic evaluation provides important information regarding fracture localization, fragment configuration, displacement severity, and treatment planning. Because superimposition of bone and soft tissues may obscure fracture lines in the mandibular region, radiographs obtained from multiple projections improve fracture characterization (Glyde and Lidbetter, 2003; Maruthi *et al.*, 2017).

Conservative treatment commonly involves mandibular bandaging; however, complete closure of the oral cavity may impair natural feeding and necessitate adjunctive procedures such as pharyngostomy, nasogastric intubation, esophagostomy, or gastrostomy (Verstraete, 2003; Maruthi *et al.*, 2017). Surgical treatment options include orthopedic wire fixation, plates, screws, acrylic splints, and external fixators. Although orthopedic wire fixation is widely used, complications such as unstable fixation, malocclusion, and wire failure have been reported (Maruthi *et al.*, 2017). Therefore, fixation techniques that provide mandibular stability, preserve early oral function, and are applicable in limited bone fragments are required in neonatal calves.

This study aimed to evaluate the clinical and radiographic outcomes of a semicircular external fixation configuration combined with transmandibular cross-linear Kirschner wire fixation for neonatal mandibular fractures localized to the symphysis mandibulae and diastema regions. The technique was assessed as a clinical modification intended to support mandibular alignment, fracture fragment apposition, and early oral function during postoperative healing.

MATERIALS AND METHODS

Ethical Approval: This study was conducted with the approval of the Kafkas University Local Ethics Committee for Animal Experiments (Approval No: KAÜ-HADYEK/2024-027) and with the consent of the cattle owners.

Study Material and Case Selection: The clinical part of the study was conducted on 20 neonatal calves of different breeds and sexes presented to the Surgery Clinic of the Kafkas University Veterinary Faculty Animal Health Teaching, Research and Application Hospital with trauma, inability to suckle, excessive salivation, and mandibular deformity. Mandibular fractures were confirmed by clinical and radiographic examinations. All fractures included in the study were naturally occurring clinical cases presented for therapeutic treatment; no mandibular fracture was experimentally induced.

The study size was primarily determined by the number of neonatal calves with mandibular fractures that were presented during the study period and fulfilled the predefined inclusion criteria. Because this clinical case series did not include a control group or a comparative intervention arm, a conventional hypothesis-driven power analysis for between-group comparisons was not methodologically applicable. Therefore, a supporting precision-based sample size justification was performed for a single proportion, using clinical and radiographic fracture healing as the primary outcome. The expected healing proportion was derived from a retrospective study of mandibular fractures in cattle, in which 52 of 63 surgically treated cases healed, corresponding to an expected healing rate of 82.5% (Zimmermann *et al*., 2022). Using a 95% confidence level, an expected proportion of 0.825, and an absolute precision of 0.17, the required sample size was calculated according to the formula $n=Z^2 \times p \times (1-p)/d^2$. This calculation yielded a minimum sample size of 19.16 animals, which was rounded up to 20 calves. Thus, the available sample size was considered adequate for estimating the primary healing proportion with moderate precision, but not for formal subgroup comparisons.

Cases with unilateral or bilateral open or closed mandibular fractures localized to the *corpus mandibulae*, *margo interalveolaris* (diastema), or *symphysis mandibulae* were included. Comminuted or multi-segmental fractures and fractures involving the *ramus mandibulae* or temporomandibular joint were excluded because of difficulties in achieving rigid stabilization, limited transcortical placement, and increased risk of iatrogenic tissue injury and postoperative complications associated with proximity to the *radix linguae* and oropharyngeal structures. All calves underwent routine preoperative clinical and laboratory evaluations, and only clinically suitable animals with informed owner consent were included.

Radiography and Ultrasonography: Radiographic examination of the mandible was performed to evaluate fracture localization, morphology, and fragment displacement. In all cases, digital radiographs were obtained in laterolateral (LL), ventrodorsal (VD), dorsoventral (DV), and laterolateral oblique projections using 60kV and 5.2mAs exposure settings. Fracture localization, fracture type, fragment alignment, displacement severity, and mandibular deformities were recorded. Postoperative radiographic follow-up was performed on days 0, 21, 45, and 60–65 using LL and VD/DV projections. Radiographic healing was assessed using a modified 5-point ordinal scoring system adapted from Leal *et al*. (2023). The system was adapted for neonatal mandibular fractures by considering fracture line visibility, callus formation, cortical bridging, fragment apposition, implant position, and restoration of mandibular continuity. Because this scoring system has not been specifically validated for neonatal calf mandibular fractures, it was used as a structured semi-quantitative follow-up tool. Radiographs were reviewed by two experienced investigators, and final healing scores were assigned by consensus for each case and follow-up time point. (Table 1). All radiographs were independently evaluated by two experienced investigators blinded to case information, and disagreements were resolved by consensus.

Ultrasonographic evaluation of the caudal mandibular region was performed using a real-time B-mode ultrasonography device with a 7.5–12MHz convex probe. The probe was positioned at the level of the *angulus mandibulae* caudoventral to the *ramus mandibulae* and directed medially for longitudinal imaging. This approach allowed evaluation of the *foramen mandibulare*, surrounding soft tissues, and anatomical localization of the *nervus alveolaris inferior*. The *arteria alveolaris mandibularis* was differentiated from neural tissue based on its pulsatile appearance.

Table 1: Modified 5-point radiographic healing scoring system used for postoperative evaluation of mandibular fracture healing.

Score	Healing Stage	Radiographic Findings	Estimated Healing (%)
0	No healing	Distinct fracture line, no callus formation	0
1	Mild healing	Early callus formation, persistent fracture line	25
2	Moderate healing	Moderate callus formation, partial cortical bridging	50
3	Advanced healing	Marked callus formation, substantial cortical bridging	>75
4	Complete healing	Complete cortical union	100

Note: This scoring system was adapted from Leal *et al.* (2023).

Implant Materials Used in the External Fixator System: Biocompatible stainless steel Kirschner wires were used for stabilization of mandibular fractures. The external fixator system consisted of four 2-mm×30-cm Kirschner wires, a 21-hole 120-mm Ilizarov aluminum semicircular external fixator ring, six wire-to-ring clamps, and 12 locking nuts for external wire connection (Fig. 1).

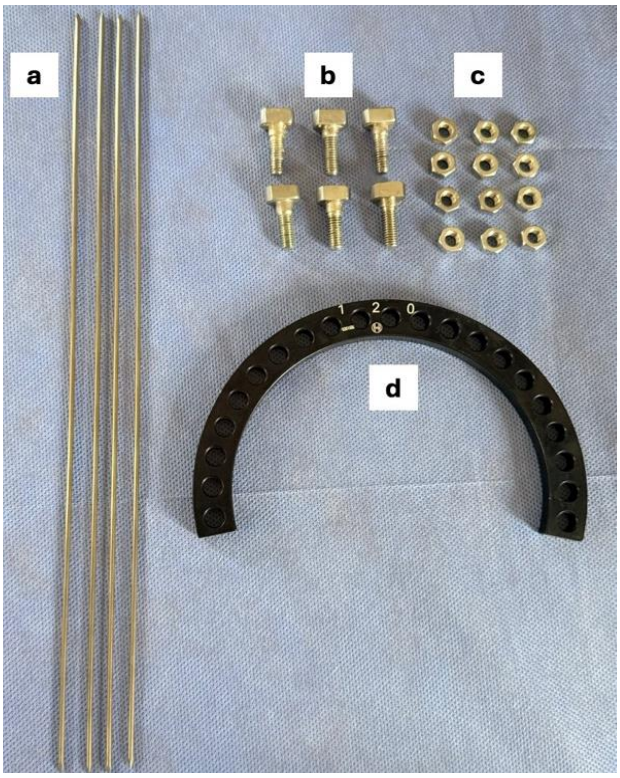

Fig. 1: Components of the semicircular external fixator system used for mandibular fracture stabilization: (a) Kirschner wires, (b) wire-to-ring connection bolts, (c) locking/connection nuts, and (d) semicircular external fixator frame.

Biochemical Parameters and Complete Blood Count Analyses: Blood samples were collected from all cases at two time points: preoperatively and at postoperative 24h for biochemical and hematological evaluation. For biochemical analysis, venous blood samples were transferred into serum tubes, and serum obtained after centrifugation was analyzed for glucose (GLU), creatinine (CREA), alkaline phosphatase (ALP), total protein (TP), alanine aminotransferase (ALT), aspartate aminotransferase (AST), gamma-glutamyl transferase (GGT), blood urea nitrogen (BUN), and albumin (ALB).

For hematological evaluation, whole blood samples collected simultaneously into EDTA tubes were analyzed for total leukocyte count (WBC), neutrophils (Neu), lymphocytes (Lym), monocytes (Mon), erythrocyte count (RBC), hemoglobin concentration (HGB), hematocrit (HCT), and platelet count (PLT). All biochemical and hematological data were recorded as ancillary perioperative systemic parameters to support clinical monitoring and to characterize the general condition of the calves, rather than as primary indicators of fixation success.

Anesthesia and Analgesia Procedure: To reduce intraoperative complications such as regurgitation and aspiration, all calves were fasted for 12h before surgery. In addition, intravenous fluid therapy was maintained during the intraoperative and postoperative periods to meet daily fluid requirements.

For sedation, xylazine hydrochloride (0.2mg/kg IM; Rompun® 2%, Bayer Türk Kimya San. Ltd. Şti., İstanbul, Türkiye) was administered, and the calves were transferred to the operating table after 10min. The inferior alveolar nerve was identified bilaterally using an extraoral ultrasound-guided approach, and 5mL of 2% lidocaine hydrochloride solution (Jetokain®, ADEKA İlaç San. ve Tic. AŞ., Türkiye) was injected perineurally on each side after negative aspiration. Surgical intervention was started 5min after clinical assessment of regional analgesia, during which the operative field was prepared and draped. Surgical duration was defined as the time from the first surgical manipulation to completion of fixation and soft tissue closure (Fig. 2).

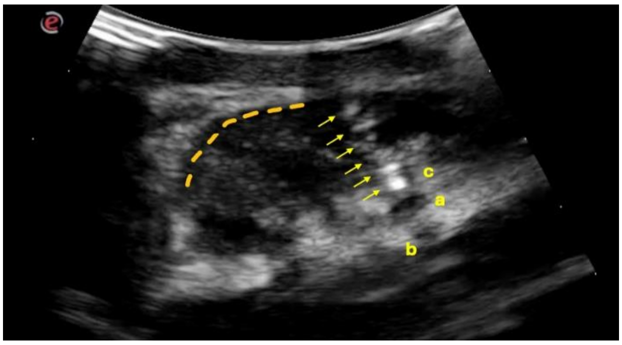

Fig. 2: Ultrasound-guided inferior alveolar nerve block at the mandibular foramen. The dashed yellow line outlines the angulus mandibularis, and arrows indicate needle advancement. (a) foramen mandibulare, (b) arteria alveolaris mandibularis, (c) perineural injection site.

Surgical Procedure: After clipping and asepsis–antisepsis of the operative region, calves were positioned in lateral recumbency and the anesthesia–analgesia protocol was applied. During lateral recumbency, the head and mandible were positioned slightly beyond the edge of the operating table. The oral cavity was accessed manually, and the mandibular fragments, including the dependent fragment, were palpated intraorally before wire placement. Kirschner wire entry and exit points were determined according to fracture localization, fragment alignment, and intraoral palpation findings. The surgical field was prepared using sterile drapes. Kirschner wire insertion sites were determined according to fracture localization, fragment length, and the anatomical position of premolar tooth roots. For external fixation, a 2-mm×30-cm Kirschner wires was first inserted horizontally into the *corpus mandibulae* at approximately a 90° angle at the level of the first/second premolar teeth, distal to the tooth roots. The Kirschner wire was advanced through the opposite mandibular cortex to achieve bilateral stabilization. A second Kirschner wireswas inserted parallel to the first wire at the level of the first premolar tooth or the immediately cranial diastemal region using the same technique. To adapt the wires to the external fixator system, they were bent approximately 135° cranially at a distance of nearly 2cm from the soft tissue surface. Subsequently, the third and fourth wires were inserted from equidistant entry points on the right and left sides of the median line of the *symphysis mandibulae* and advanced crosswise from the cranial fracture fragment toward the contralateral *corpus mandibulae* using the crossed Kirschner wire fixation technique. This configuration aimed to achieve multiplanar stabilization of the fracture line (Fig. 3).

All wires were positioned to correspond with opposing and symmetrical holes of the external fixator ring. After necessary alignment and adjustments of the external fixator system to maintain anatomical reduction and provide sufficient stabilization, the Kirschner wires were secured using wire-to-ring clamps (Fig. 4).

Following anatomical reduction of fracture fragments associated with intraoral open wounds, oral mucosal defects were closed using appositional sutures with nonabsorbable 0–2/0 polypropylene suture material (Prolene® 2-0, Ethicon Inc., Somerville, NJ, USA). After irrigation of the surgical field and oral cavity with antiseptic solutions, the surgical procedure was completed.

Postoperative Analgesia, Feeding and Follow-Up: For preemptive analgesia and pain management, meloxicam (0.5mg/kg; Bavet Meloxicam®, Bavet İlaç San. ve Tic. A.Ş., İstanbul, Türkiye) was administered subcutaneously every other day for a total of five doses.

Antibiotic therapy initiated preoperatively was continued postoperatively using amoxicillin trihydrate (Clamoxyl®, Zoetis Hayvan Sağlığı Ltd. Şti., İstanbul, Türkiye) administered intramuscularly at 1mL/10 kg every other day for a total of five doses. To prevent Kirschner wire tract infections, rifamycin sodium (RİF® 125mg, Koçak Farma İlaç ve Kimya Sanayi A.Ş., İstanbul, Türkiye) was locally injected into wire insertion sites at 7-day intervals for a total of five applications.

All calves were hospitalized for 24h for postoperative monitoring. Following discharge, owners were instructed to clean Kirschner wire insertion sites daily with 10% povidone-iodine solution and monitor for discharge or Kirschner wire loosening. During hospitalization and follow-up, a standardized postoperative follow-up form was used to record predefined adverse outcome categories, including Kirschner wire insertion-site complications, Kirschner wire loosening, osteomyelitis, angular deformity or malunion, marked secondary displacement, respiratory complications, persistent feeding problems, and death before completion of follow-up.

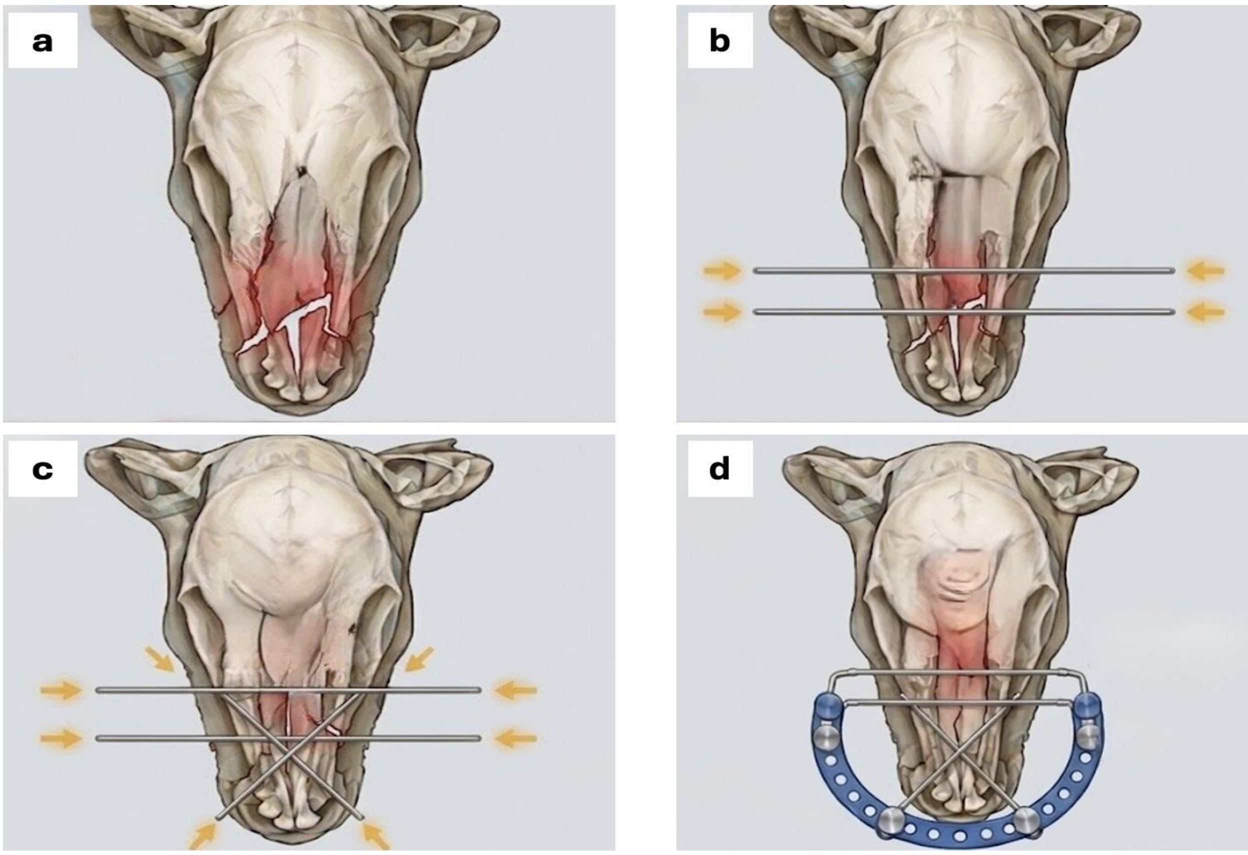

Fig. 3: Schematic illustration of the semicircular external fixation technique. (a) Appearance of the mandibular fracture line before fixation; (b–c) placement of the linear and crossed transmandibular wires; (d) completed fixation after connecting the wires to the semicircular external fixator ring system.

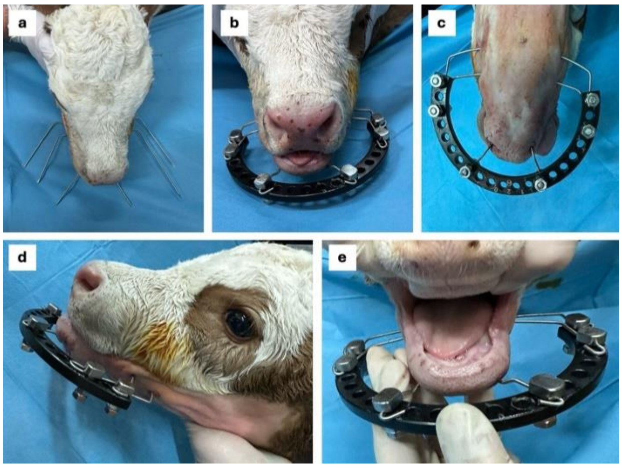

Fig. 4: Stabilization of the mandibular fracture using a semicircular external fixator. (a) Placement of Kirschner wires, (b–c) connection of the ring fixator to the Kirschner wires, (d) lateral view, and (e) rostral view of postoperative stabilization.

Postoperative feeding recovery was assessed descriptively based on initiation of controlled bottle feeding after the 6–8h restriction period, tolerance of bottle \feeding during follow-up, and the presence or absence of persistent feeding difficulty requiring alternative feeding support. Natural suckling from the dam was not used as an outcome measure because controlled bottle feeding was intentionally preferred to minimize uncontrolled mechanical loading on the fixation system and prevent damage to the dam or implant system.

Statistical Analyses: All statistical analyses were performed using SPSS version 21.0 (SPSS® Inc., Chicago, IL, USA). Radiographic healing scores on postoperative days 0, 21, 45, and 60–65 were considered the main structured outcome measure for fracture healing. Fixation-related clinical findings, including mandibular alignment, marked secondary displacement, implant position, oral feeding ability, complications, and implant removal, were recorded and summarized descriptively.

Radiographic healing scores were analyzed longitudinally in calves that completed all radiographic follow-up time points. Cases with incomplete follow-up due to death were excluded from the statistical comparison and reported descriptively. Since the scores were ordinal repeated-measure data, changes over time were evaluated using the Friedman test, and Kendall's W was reported as the effect size. Pairwise comparisons between consecutive follow-up time points were performed using the Wilcoxon signed-rank test with Bonferroni correction.

Vital, hematological, and biochemical variables measured preoperatively and at postoperative 24h were analyzed as ancillary perioperative systemic parameters, not as primary indicators of fixation success. Data distribution was assessed using the Shapiro–Wilk test. For normally distributed paired variables, the paired t-test was used and paired mean differences were reported with 95% confidence intervals and Cohen's dz. For non-normally distributed paired variables, the Wilcoxon signed-rank test was used and the corresponding effect size was reported. Continuous variables were expressed as mean±standard deviation, and $P<0.05$ was considered significant. Surgical duration was recorded for each calf and summarized descriptively as mean ± standard deviation with minimum and maximum values.

RESULTS

Clinical Findings Related to the Cases: All cases were in the neonatal period, and anamnesis revealed that mandibular fractures developed secondary to excessive traction and improper obstetrical manipulations performed using ropes, chains, or manual traction applied to the mandible during assisted delivery. In Cases 2 and 6, traction was reportedly continued using a rope placed around the cervical region after mandibular fracture formation to complete delivery assistance.

Clinical examination revealed marked hemorrhagic salivation, mandibular deformity, malocclusion, mandibular instability, pain on palpation, weakness, anorexia, depression, and traumatic soft tissue lesions within the oral cavity in all cases. Traumatic cervical changes were consistent with severe soft tissue injury and upper airway compression. Demographic data, clinical findings, and fracture characteristics are summarized in Table 2.

Table 2: Demographic data and morphological and clinical characteristics of mandibular fractures in the cases.

Case No	Breed	Sex	Age (days)	Fracture Pattern	Localization	Fracture Exposure	Laterality
1	Simmental	Female	1	Avulsion-type physeal fracture	Symphysis mandibula	Open	Bilateral
2	Simmental	Female	3	Avulsion-type physeal fracture	Symphysis mandibula	Closed	Bilateral
3	Simmental	Male	5	Transverse fracture	Diastema	Closed	Bilateral
4	Simmental	Female	4	Oblique fracture	Diastema	Closed	Bilateral
5	Simmental	Female	3	Transverse fracture	Diastema	Closed	Unilateral
6	Simmental	Male	5	Transverse fracture	Diastema	Closed	Bilateral
7	Montofon	Male	1	Avulsion-type physeal fracture	Symphysis mandibula	Closed	Bilateral
8	Simmental	Male	1	Oblique fracture	Diastema	Open	Bilateral
9	Simmental	Male	2	Avulsion-type physeal fracture	Symphysis mandibula	Closed	Bilateral
10	Angus	Female	4	Oblique fracture	Diastema	Open	Bilateral
11	Simmental	Male	5	Oblique fracture	Diastema	Closed	Bilateral
12	Simmental	Male	2	Transverse fracture	Diastema	Open	Bilateral
13	Simmental	Male	1	Avulsion-type physeal fracture	Symphysis mandibula	Closed	Bilateral
14	Simmental	Male	1	Transverse fracture	Diastema	Closed	Bilateral
15	Montofon	Male	2	Avulsion-type physeal fracture	Symphysis mandibula	Open	Bilateral
16	Montofon	Male	2	Avulsion-type physeal fracture	Symphysis mandibula	Open	Bilateral
17	Simmental	Male	4	Avulsion-type physeal fracture	Symphysis mandibula	Closed	Bilateral
18	Montofon	Female	3	Avulsion-type physeal fracture	Symphysis mandibula	Open	Bilateral
19	Simmental	Female	4	Transverse fracture	Diastema	Closed	Unilateral
20	Simmental	Male	2	Oblique fracture	Diastema	Closed	Unilateral

In 10 calves presented 3–5 days after fracture formation (Cases 2, 3, 4, 5, 6, 10, 11, 15, 17, and 19), severe pain, excessive salivation, and mechanical restriction of suckling were observed. Anamnesis indicated that these calves had been forced to feed orally from the dam or by bottle before admission and had remained in the birth canal for a prolonged period. Clinical findings consistent with aspiration pneumonia were observed, with more severe pneumonia in Cases 2 and 11. Preoperative thoracic radiographs demonstrated increased bronchial/interstitial opacity and diffuse pulmonary consolidation, particularly in the cranioventral lung fields.

After confirmation of regional analgesia, the mean surgical duration was 51.8±9.0min, ranging from 35 to 65min. Longer operative times were generally associated with open fracture cases requiring additional soft tissue closure. No calf required supplemental anesthetic administration during surgery, and no clinically evident pain-related response was observed throughout the operative period.

Preoperative and Postoperative Vital, Hematological, and Biochemical Findings: Vital, hematological, and biochemical findings were evaluated as ancillary perioperative systemic parameters and were not considered primary indicators of fixation success. Paired differences, 95% confidence intervals, and effect size estimates are presented in Table 3 to support interpretation beyond P-values, particularly for parameters with wide inter-individual variability.

Among vital parameters, only body temperature showed a significant postoperative decrease (P=0.018). In the biochemical profile, TP increased significantly (P=0.0166), whereas GGT activity decreased significantly (P=0.0067). No significant postoperative differences were detected in heart rate, respiratory rate, or the hematological variables presented in Table 3. These findings were interpreted as supportive systemic monitoring data and were not used as primary indicators of fixation success (Table 3).

Radiography and Ultrasonography Findings: Radiographic evaluation included detailed assessment of fracture localization, fracture configuration, displacement severity, and fragment stability. In addition to fracture findings, marked traumatic soft tissue changes associated with improper manipulations using thin ropes were observed in the mandibular region. Increased soft tissue opacity and localized thickening were evident along the compression line created by the rope, whereas constricted regions showed distinct radiolucent linear opacities (Fig. 5). In nine cases, avulsion-type physeal fractures of the incisive mandibular segment were observed rather than complete symphyseal separation. In these cases, mandibular arch continuity was partially preserved, although fracture fragments remained attached mainly by soft tissues and were ventrally displaced. In 11 cases, fracture lines were localized in the diastemal region, predominantly showing oblique or transverse configurations. Marked fragment displacement, override deformity, and rotational instability were common in diastemal fractures, whereas unilateral involvement was observed in only three cases (Table 2).

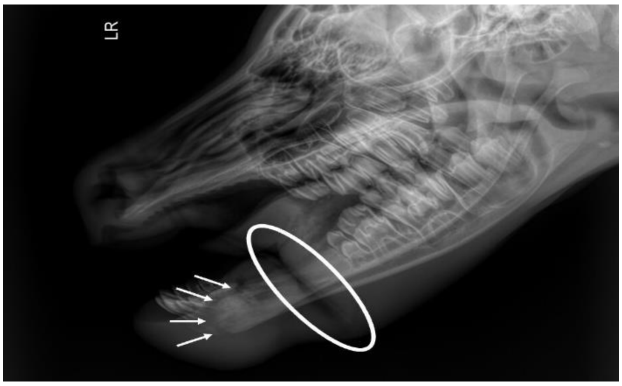

Fig. 5: Latero-lateral radiograph shows soft tissue constriction in the area indicated by the circle, and an avulsion-type physeal fracture line at the level of the symphysis mandibula in the area indicated by the arrows.

Table 3: Ancillary preoperative and postoperative vital, hematological, and biochemical findings with paired differences, 95% confidence intervals, effect sizes and P values.

Parameters	Preoperative (Mean±SD) (n=20)	Postoperative 24h (Mean±SD) (n=20)	Mean difference, Post–Pre, 95% CI	Effect size	P value
Body Temperature (°C)	38.70±0.93	37.70±1.05	-1.00 (-1.80 to -0.20)	dz: -0.69	0.0179
Heart Rate (min)	129.73±18.03	124.00±19.19	-5.73 (-21.38 to 9.91)	dz:-0.20	0.4449
Respiratory Rate (min)	50.47±11.97	49.93±11.65	-0.53 (-8.77 to 7.70)	dz:-0.04	0.8915
WBC (10^9/L)	8.71±4.01	7.45±2.61	-1.13 (-3.85 to 1.59)	r: 0.11	0.3735
Neu (10^9/L)	5.78±3.97	4.26±2.12	-1.48 (-3.87 to 0.92)	r: 0.34	0.2412
Lym (10^9/L)	2.45±0.55	2.66±0.69	0.18 (-0.20 to 0.55)	r: 0.21	0.2958
Mon (10^9/L)	0.22±0.27	0.30±0.22	0.11 (-0.10 to 0.32)	dz: 0.29	0.2347
Eos (10^9/L)	0.03±0.02	0.03±0.01	0.00 (-0.01 to 0.01)	dz: 0.19	0.3962
RBC (10^{12}/L)	6.66±1.08	6.00±1.70	-0.67 (-1.61 to 0.27)	dz: -0.40	0.1866
HGB (g/dL)	9.09±2.33	8.71±2.25	-0.27 (-1.70 to 1.15)	dz: -0.11	0.601
HCT (%)	29.20±4.76	26.71±7.30	-2.96 (-6.78 to 0.86)	dz: -0.43	0.2415
PLT (10^9/L)	526.71±377.62	653.29±696.04	126.57 (-112.91 to 366.05)	r: 0.13	0.1608
GLU (mg/dL)	81.67±18.77	90.45±59.12	8.78 (-24.58 to 42.14)	r:0.15	0.5614
CREA (mg/dL)	1.28±0.87	0.87±0.67	-0.41 (-0.94 to 0.13)	r:0.31	0.2293
ALP (U/L)	192.60±87.62	171.33±49.18	-21.27 (-76.02 to 33.49)	dz:-0.22	0.4188
TP (g/dL)	4.03±0.46	5.1±1.40	1.07 (0.23 to 1.92)	dz:0.70	0.0166
ALT (U/L)	24.91±7.64	27.42±13.46	2.51 (-5.40 to 10.41)	dz:0.18	0.5076
AST (U/L)	127.75±49.26	99.29±51.41	-28.46 (-58.12 to 1.20)	dz:-0.53	0.0587
GGT (U/L)	321.20±341.70	152.00±158.58	-169.20 (-287.61 to -50.79)	r:0.70	0.0067
BUN (mg/dL)	8.38±4.23	8.92±7.71	0.54 (-2.57 to 3.65)	dz:0.10	0.7152
ALB (g/dL)	2.29±0.75	2.64±0.64	0.35 (-0.18 to 0.88)	r:0.39	0.1608

Note: Values are presented as mean±SD. Differences were calculated as postoperative 24h minus preoperative values using paired individual data. Body temperature, heart rate, respiratory rate, Mon, Eos, RBC, HGB, HCT, ALP, TP, ALT, AST, and BUN were analyzed using paired t-tests, and Cohen's dz was reported as the effect size. WBC, Neu, Lym, PLT, GLU, CREA, GGT, and ALB were analyzed using the Wilcoxon signed-rank test, and r was reported as the effect size. Bold P values indicate P<0.05. These variables were analyzed as ancillary perioperative parameters and were not considered primary indicators of fixation success.

Postoperative radiographs obtained on days 0, 21, 45, and 60–65 demonstrated an initial healing score of "Score 0" in all cases, followed by gradual score progression during follow-up. The temporal distribution of postoperative radiographic healing scores and final clinical outcomes is presented in Table 4.

Table 4: Temporal distribution of postoperative radiographic healing scores.

Case No	Day 0 Score	Day 21 Score	Day 45 Score	Day 60-65 Score	Overall Evaluation
1	0	1	2	4	Successful healing
2	0	2	3	Ex	Ex due to pneumonia; final score 3
3	0	2	3	4	Successful healing
4	0	2	3	4	Successful healing
5	0	2	3	4	Successful healing
6	0	2	3	4	Successful healing
7	0	1	3	4	Successful healing
8	0	1	Ex	-	Ex due to pneumonia; final score 1
9	0	2	3	4	Successful healing
10	0	1	2	3	Moderate healing
11	0	1	3	4	Successful healing
12	0	1	2	3	Moderate healing
13	0	1	3	4	Successful healing
14	0	2	3	4	Successful healing
15	0	1	3	4	Successful healing
16	0	1	2	4	Successful healing
17	0	2	3	4	Successful healing
18	0	1	3	4	Successful healing
19	0	2	3	4	Successful healing
20	0	2	3	4	Successful healing

Note: Ex= exitus before completion of follow-up.

Outcome was summarized separately for survival, radiographic healing, fixation-related complications, respiratory complications, feeding problems, and deaths before completion of follow-up. Eighteen of 20 calves survived until implant removal and completed the radiographic follow-up period, resulting in a survival rate of 90%. Two calves died before completion of follow-up due to pneumonia, corresponding to an overall mortality rate of 10%. These deaths were not classified as direct fixation failures because no catastrophic implant failure or marked loss of fixation was observed before death. Complete radiographic healing was documented in 16 of 20 enrolled calves and in 16 of 18 calves that completed follow-up. Two surviving calves remained at Score 3 on days 60–65 and were classified as moderate/incomplete healing cases. Fixation-related complications were observed in these two calves and consisted of persistent angular deformity associated with postoperative osteomyelitis and cortical widening with Kirschner wire loosening at the insertion sites. After controlled bottle feeding was initiated, persistent postoperative feeding difficulty was not recorded in the surviving calves. Outcome and complication data were summarized separately for survival, radiographic healing, fixation-related complications, respiratory complications, feeding problems, and deaths before completion of follow-up. Controlled bottle feeding was initiated after the 6–8 h postoperative restriction period. In the surviving calves, bottle feeding was maintained during the healing period, and persistent postoperative feeding difficulty requiring alternative feeding support was not recorded (Table 5).

In calves that completed all radiographic follow-up time points (n=18), radiographic healing scores increased progressively over time. Median scores increased from 0 (IQR:0–0) on day 0 to 1.5 (IQR:1–2) on day 21, 3 (IQR:3–3) on day 45, and 4 (IQR:4–4) on days 60–65. Friedman analysis showed a significant increase in radiographic healing scores over time (χ^2=54.000, df=3, P<0.001, Kendall's W=1.00). Kendall's W indicated complete concordance in the temporal ranking of radiographic healing scores across the four follow-up time points. This finding reflected the progressive within-case increase in healing scores over time and did not indicate identical absolute scores among calves at each time point. Pairwise Wilcoxon signed-rank tests with Bonferroni correction showed significant increases between consecutive follow-up periods, including day 0 to day 21, day 21 to day 45, and day 45 to days 60–65 (P<0.001 for all comparisons).

Table 5: Complications and follow-up outcomes after semicircular external fixation combined with transmandibular cross-linear Kirschner wire fixation.

Outcome / complication	Case(s)	n/N (%)	Interpretation
Death before completion of follow-up	2, 8	2/20 (10.0)	Pneumonia; non-fixation-related
Wire insertion-site infection/osteomyelitis	10, 12	2/20 (10.0)	Delayed healing
Wire loosening/cortical widening	10, 12	2/20 (10.0)	Insertion-site widening
Angular deformity/malunion	10, 12	2/20 (10.0)	Score 3 cases
Secondary displacement/implant failure	None	0/20 (0.0)	Not observed
Persistent feeding difficulty	None in survivors	0/18 (0.0)	Not recorded

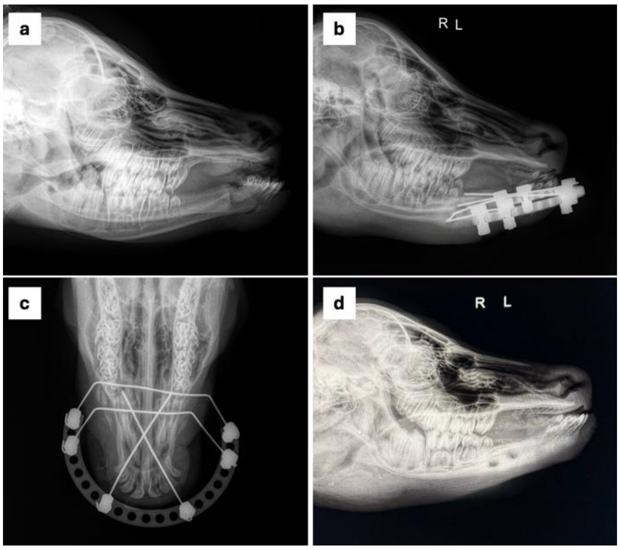

Fig: 6. Radiographic follow-up images of Case 17. (a) preoperative latero-lateral view; (b–c) day 60 latero-lateral and dorsoventral views showing mandibular healing; (d) latero-lateral view after external fixator removal.

In lateral projections, marked radiopaque superimposition caused by metallic external fixator components limited evaluation of the fracture line, callus formation, and cortical bridging (Fig. 6). This was considered the main imaging limitation affecting objective assessment of fracture healing on lateral radiographs. Therefore, alternative projections (DV–VD), which allowed better visualization of osseous structures, were prioritized for radiographic healing assessment (Fig. 7).

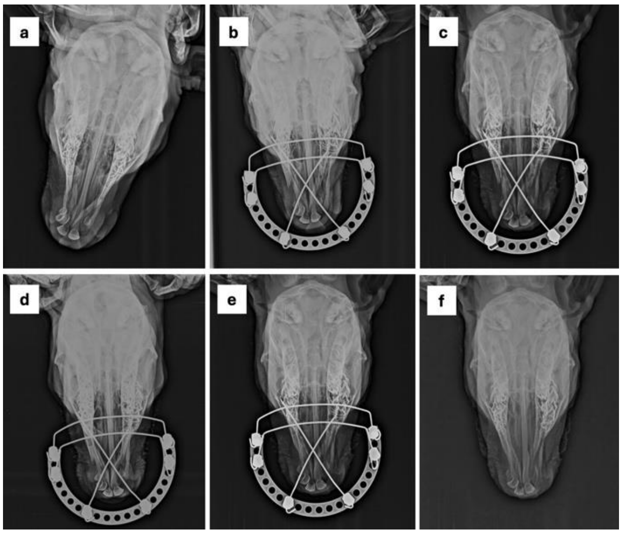

Fig. 7: Radiographic healing of Case 11. (a) Preoperative fracture and displacement; (b) postoperative day 0 after reduction and fixation; (c–e) days 21, 45, and 60 showing progressive healing; (f) day 65 showing mandibular alignment and fracture union.

Ultrasonographic examination revealed that trauma-associated soft tissue edema and hematoma partially impaired visualization of anatomical structures in some cases. Optimal imaging of the foramen mandibulare and surrounding soft tissues was more difficult in calves with severe soft tissue trauma.

DISCUSSION

Rostral mandibular and diastemal fractures in neonatal calves represent clinically important injuries because mandibular instability can rapidly impair controlled oral feeding, fragment apposition, and postoperative recovery. In the present case series, the semicircular external fixator combined with transmandibular cross-linear Kirschner wire fixation was associated with maintenance of mandibular alignment, absence of marked secondary displacement, and progressive radiographic healing in most surviving calves. These findings support the clinical applicability of the configuration in selected neonatal calves; however, they should not be interpreted as evidence of biomechanical superiority over other fixation methods. The etiological background of these fractures is clinically important because most neonatal mandibular fractures are associated with assisted delivery and excessive traction forces. Yurdakul (2023) reported that all mandibular fractures in a five-case series developed secondary to excessive traction applied using ropes or chains attached to the mandible during assisted delivery. Similarly, previous studies identified improper obstetrical manipulations associated with dystocia as a major cause of neonatal mandibular fractures (Mellor and Stafford, 2004; Arıcan *et al.*, 2014; Yurdakul, 2018). In the present study, all calves were neonates and fracture development was associated with obstetrical intervention, supporting that these fractures are largely preventable iatrogenic or assistance-related injuries. These findings indicate that traction forces during dystocia should be directed toward the extremities or appropriate obstetrical structures rather than the mandible, and veterinary intervention should not be delayed.

This traction-related mechanism may also explain the fracture distribution observed in the present cohort. Although mandibular fractures are generally unilateral, bilateral cases have also been reported (Fessler and Adams, 1996; Gosai *et al.*, 2022). In the present study, bilateral fractures were identified in 17 of 20 neonatal calves, whereas only three cases were unilateral. The high incidence of bilateral fractures was attributed to simultaneous transmission of excessive traction forces applied to both mandibles during assisted delivery using ropes, chains, or manual traction. Symmetrical traction directed toward the rostral mandible and diastema likely generated concurrent bending and compressive stresses, predisposing to bilateral fracture formation.

Functionally, mandibular fractures in neonatal calves are clinically important because they may impair mastication, suckling, and feeding, resulting in rapid deterioration of body condition (Della Valle *et al.*, 2018). Therefore, treatment success depends not only on fragment apposition but also on maintenance of mandibular continuity, preservation of oral function, control of load distribution during healing, and improvement of general health status. Clinical findings observed in the present study, including mandibular deformity, fragment displacement, oral instability, and feeding difficulty, were consistent with previous reports and further emphasized the necessity of surgical stabilization.

Healthy calves reportedly have neutrophil percentages ranging from 25 to 45% (Steffl and Nautscher, 2022). Neutrophilia is frequently associated with bacterial systemic infections, particularly respiratory disease (Levine and Andreasen, 2022). In the present study, aspiration pneumonia was radiographically confirmed in calves with mandibular fractures. Despite antibiotic and anti-inflammatory treatment, neutrophil percentages remained elevated during both preoperative and postoperative periods, likely due to secondary bacterial infections associated with aspiration pneumonia.

From a treatment perspective, external coaptation may be considered a simple and economical option for selected rostral mandibular fractures. Taguchi and Hyakutake (2012) described fiberglass external coaptation as a simple and economical treatment for rostral mandibular fractures; however, persistent angular deformities were attributed to insufficient longitudinal compression. In the present study, the semicircular external fixator combined with transmandibular cross-linear Kirschner wire fixation allowed direct engagement of the fracture fragments and may have contributed to better clinical control of dorsoventral, mediolateral, and rotational instability. Although this mechanical effect was not biomechanically tested, the absence of marked secondary displacement, preservation of implant stability, and progressive radiographic healing suggest that the technique provided clinically sufficient stabilization, particularly in displaced neonatal fractures associated with impaired feeding.

The indication for surgical intervention in neonatal mandibular fractures should be determined by the degree of fracture displacement, the presence of oral instability, and the calf's ability to suckle effectively. Although selected mandibular fractures may be managed conservatively, surgical stabilization remains an important option when anatomical reduction, functional stability, and early restoration of oral function are required (Johnson and Hulse, 2002; Karabağlı and Eravcı, 2014). Zimmermann *et al*. (2022) reported an 82.5% recovery rate after surgical treatment of bovine mandibular fractures. In line with these findings, the present study suggests that stable external fixation may support suckling ability and functional recovery in neonatal calves with dystocia-related mandibular fractures.

Given the need for stable fixation with limited soft tissue disruption, external skeletal fixation offered several practical advantages in the present cases. External fixators offer important advantages, including preservation of local vascularization, reduced soft tissue trauma, early functional use, and easy implant removal (Vogel and Anderson, 2014; Della Valle *et al*., 2018). In the present study, stabilization was achieved using transmandibular cross-linear 2-mm Kirschner wires combined with a semicircular external fixator ring. This minimally invasive configuration preserved tooth roots and surrounding soft tissues while supporting mandibular symmetry and occlusal alignment. The choice of external ring configuration may vary according to fracture localization and the required fixation arc. Rings with extended arms may be useful in mandibular fractures extending toward the caudal region because they provide a wider area for implant connection. However, in the present study, the fractures were localized to the symphysis mandibulae and diastema regions, where the semicircular ring provided sufficient access for cross-linear wire placement and stable external fixation. For more caudal mandibular fractures, implant configuration and wire orientation should be planned separately according to fracture morphology and regional anatomical constraints.

The findings of the present study suggest that external fixation may be considered a practical alternative stabilization strategy for selected neonatal mandibular fractures, consistent with the clinical applicability of external fixation reported by Yurdakul (2023). In the present study, serial radiographic scoring at defined postoperative intervals enabled structured follow-up of callus formation, cortical bridging, and mandibular continuity. This approach allowed fracture healing to be assessed systematically rather than relying only on clinical improvement. However, radiopaque superimposition of the aluminum semicircular ring, particularly on lateral radiographs, partially limited visualization of the fracture line and callus development. Therefore, carbon fiber rings may offer a more favorable option for future radiographic follow-up by reducing implant-related superimposition. Functional recovery was interpreted as tolerance of controlled bottle feeding rather than objectively measured natural suckling performance. Standardized suckling scores, quantitative milk intake, serial body weight gain, or structured owner-reported feeding assessments were not performed. Therefore, feeding outcome was limited to the ability to resume and maintain controlled oral feeding during follow-up. Correct timing of ESF removal is critical in neonatal mandibular fractures. Fracture healing is rapid in newborn calves, and earlier implant removal after sufficient stability may improve patient comfort. Although early implant removal after fibrous callus formation has been suggested (Mahla *et al*., 2022), clinical improvement or early callus formation may not always indicate adequate cortical bridging, particularly in bilateral mandibular fractures exposed to continuous functional use during suckling, chewing, and mandibular movement. Therefore, in the present study, ESF was removed on days 60–65 after radiographic confirmation of callus maturation and cortical continuity. This conservative approach was preferred as a precautionary strategy against instability, secondary displacement, and malunion. However, when sufficient fracture stability is objectively confirmed by clinical and radiographic findings, earlier ESF removal may be a clinically reasonable option to improve patient comfort. Implant-entry site complications remain an important consideration in external fixation. wire loosening and Kirschner wire insertion-site infection are common complications of external fixation. Previous studies reported these complications in neonatal calves treated with acrylic fixators (Kraus *et al*., 1998; Anderson *et al*., 2003; Altuğ *et al.,* 2017; Yurdakul, 2023). In the present study, most surviving calves showed progressive healing; however, two cases remained at Score 3 by days 60–65, with persistent angular deformity associated with postoperative osteomyelitis and cortical widening with loosening at the wire insertion sites. These findings indicate that the semicircular configuration may be clinically useful, but treatment success depends on careful wire-site care, infection control, and standardized postoperative monitoring. Mandibulo-alveolar nerve block combined with sedation has been described as a safe and economical analgesic technique in large ruminants (Semieka and Misk, 2003; Re *et al*., 2016). In the present study, sedation combined with bilateral ultrasound-guided inferior alveolar nerve block was preferred instead of sedation followed by general anesthesia, as this approach reduced the anesthetic burden, avoided airway management and inhalation anesthesia, and supported the practical applicability of the technique in neonatal calves. This protocol provided adequate intraoperative analgesia for a mean surgical duration of 51.8±9.0min (range, 35–65min), without supplemental anesthetic administration or clinically evident pain-related responses. Patient positioning remains an important consideration under this protocol. Dorsal recumbency may provide a more symmetrical operative field and facilitate bilateral transmandibular wire placement; however, lateral recumbency with the head and mandible positioned beyond the edge of the operating table represented a practical compromise in sedated calves. The main limitation of this approach is the need for careful intraoperative control of occlusion, mandibular alignment, and wire direction.

Limitations of the Study: Although the sample size was supported by a precision-based calculation, it was not sufficient for hypothesis-driven subgroup comparisons according to fracture localization, open or closed fracture type, or postoperative complications.

The expected healing proportion used for sample size justification was derived from previously published mixed cattle mandibular fracture data, not from neonatal calves treated with the identical semicircular external fixation technique.

Radiographic healing scores were recorded as final consensus scores; therefore, interobserver agreement could not be retrospectively calculated.

The absence of a comparison group limited conclusions regarding superiority, cost-effectiveness, and relative mechanical performance compared with other fixation methods.

Feeding recovery was not evaluated using standardized suckling scores, quantitative milk intake, serial body weight gain, or structured owner-reported assessments; therefore, functional oral recovery was interpreted descriptively.

Vital, hematological, and biochemical comparisons were limited to calves with complete paired preoperative and postoperative 24 h data and should be interpreted as ancillary descriptive findings rather than primary determinants of fixation outcome.

Conclusions: In conclusion, the semicircular external fixation technique combined with transmandibular cross and linear Kirschner wire fixation appears to be a practical and clinically applicable treatment option for selected neonatal calves with mandibular fractures. In the present case series, this technique supported restoration of mandibular continuity, preservation of suckling and bottle-feeding ability, and progressive radiographic healing in most surviving calves. The limited surgical exposure, external accessibility of the fixation system, and possibility of postoperative adjustment or revision when necessary may increase its clinical usefulness under large-animal practice conditions. However, the findings should be interpreted within the limits of a non-comparative clinical case series. Treatment success depends not only on fixation-related stability but also on careful case selection, regular Kirschner wire insertion-site care, clinical monitoring, adequate nutritional support, and appropriate systemic therapy. Further comparative studies are required to determine the relative clinical advantages of this configuration over other fixation methods.

Declarations

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Conflict of Interest: The authors declare that they have no conflict of interest.

Data Availability: The data supporting the findings of this study are included in the manuscript. Additional data are available from the corresponding author upon reasonable request.

Ethics Statement: This clinical study was conducted in accordance with national animal welfare regulations and institutional ethical principles. Ethical approval was obtained from the Kafkas University Animal Experiments Local Ethics Committee (Approval No: KAÜ-HADYEK/2024-027). Written or verbal owner consent was obtained before clinical treatment and follow-up procedures.

Authorship Contribution: Ersin TANRIVERDİ, İsa ÖZAYDIN, Uğur AYDIN, Alican YILMAZ: Writing, review and editing, original draft, visualization, validation, methodology, Investigation, formal analysis, conceptualization. Celal Şahin ERMUTLU, Özgür AKSOY: Data curation, supervision, review and editing. Mert SEZER, Enes AKYÜZ: Writing, formal analysis, data curation.

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REFERENCES

Aksoy O, Ozaydin I, Kilic E, *et al.*, 2009. Evaluation of fractures in calves due to forced extraction during dystocia: 27 cases (2003-2008). Kafkas Üniversitesi Veteriner Fakültesi Dergisi 15:339-344. https://doi.org/10.9775/kvfd.2008.100-a

Altuğ ME, İşler CT, Yurtal Z, *et al.*, 2017. Bir köpekte rostral mandibula kırığının akrilik eksternal fiksatör ile tedavisi. Fırat Üniversitesi Sağlık Bilimleri Veteriner Dergisi 31:261-264.

Anderson GM, Lewis DD, Radasch RM, *et al.*, 2003. Circular external skeletal fixation stabilization of antebrachial and crural fractures in 25 dogs. Journal of the American Animal Hospital Association 39:479-498. https://doi.org/10.5326/0390479

Arıcan M, Erol H, Esin E, *et al.*, 2014. A retrospective study of fractures in neonatal calves: 181 cases (2002-2012). Pakistan Veterinary Journal 34:247-250.

Canatan U and Küken EE, 2026. Concurrent dentoalveolar fracture and lip avulsion in a newborn calf after dystocia: A case report. Bulgarian Journal of Veterinary Medicine (Online first). https://doi.org/10.15547/bjvm.2026-0031

Della Valle G, Guccione J, Pasolini MP, *et al.*, 2018. External skeletal fixation for surgical repair of a bilateral mandible fracture in a Mediterranean buffalo. Pakistan Veterinary Journal 38:456-458. https://doi.org/10.29261/pakvetj/2018.073

Fessler JF and Adams SB, 1996. Decision making in ruminant orthopedics. Veterinary Clinics of North America: Food Animal Practice 12:1-18. https://doi.org/10.1016/S0749-0720(15)30434-5

Glyde M and Lidbetter D, 2003. Management of fractures of the mandible in small animals. In Practice 25:570-585. https://doi.org/10.1136/inpract.25.10.570

Gosai RK, Patel AN, Patel JB, *et al.*, 2022. Surgical immobilization of bilateral mandibular fracture in calves. The Pharma Innovation Journal 11:1995-1997.

Johnson AL and Hulse DA, 2002. Management of specific fractures. In: Small Animal Surgery (Fossum TW, ed), 2nd Ed, Mosby, St. Louis, USA, pp:901-913.

Karabağlı M and Eravcı E, 2014. Mandibula kırıklarında tanı ve tedavi. Turkiye Klinikleri Journal of Veterinary Sciences 5:36-40.

Kraus KH, Wotton HM, *et al.*, 1998. Type II eksternal fixation, using new clamps and positive profile threaded pins, for treatment of fractures of the radius and tibia in dogs. Journal of the American Veterinary Medical Association. 212:1267-1270.

Kumar KK, Singh BP and Kumar TS, 2023. Surgical management of mandibular symphyseal fracture in bovine. Intas Polivet 24:47-49.

Leal RA, Lambrechts NE, Crowley JD, *et al.*, 2023. Comparison of radiographic scoring systems for assessment of bone healing after tibial plateau leveling osteotomy in dogs. Frontiers in Veterinary Science 10:1147386. https://doi.org/10.3389/fvets.2023.1147386

Levine DN and Andreasen CB, 2022. Neutrophil function and response. In: *Schalm's* Veterinary Hematology (Weiss DJ, Wardrop KJ, Harr KE, Seelig DM and Brooks MB, eds), 7th Ed, Wiley-Blackwell, Hoboken, USA, pp:339-346. https://doi.org/10.1002/9781119500537.ch43

Locher I, Nuss K, Rediger D, *et al.*, 2021. Surgical debridement and primary closure of the oral mucosa for repair of open mandibular pars incisiva fractures in three neonatal calves. Journal of the American Veterinary Medical Association 258:1254-1258.

Mahla JK, Amin NR, Dabhi PB, *et al.*, 2022. Management of dystocia-induced mandibular fracture in newborn calves: A review of 14 cases. The Pharma Innovation Journal 11:1156-1157.

Maruthi ST, Dinesh PT and Chandy G, 2017. Oesophagostomy and tape muzzling for management of mandibular fracture in a calf. Intas Polivet 18:276-279.

Mellor DJ and Stafford KJ, 2004. Animal welfare implications of neonatal mortality and morbidity in farm animals. The Veterinary Journal 168:118-133. https://doi.org/10.1016/j.tvjl.2003.08.004

Re M, Blanco-Murcia J, Villaescusa A, *et al*., 2016. Comparison of paravertebral blockade techniques with and without ultrasound guidance in calves. American Journal of Veterinary Research 77:1187-1193.

Reddy PVV, Raj P, Simon S, *et al*., 2024. Novel approach in treating calf's rostral mandible fracture using interfragmentary wiring: A case study. International Journal of Veterinary Sciences and Animal Husbandry 9:320-322.

Remala S, Sagi S and Yeturi S, 2017. Surgical repair of mandibular fracture in a newborn calf. Intas Polivet 18:273-276.

Semieka MA and Misk NA, 2003. Radiographic studies on the mandible of buffaloes and camels with special reference to mandibulo-alveolar nerve block. Journal of Camel Practice and Research 10:9-16.

Steffl M and Nautscher N, 2022. Subconjunctival bleedings in neonatal calves: A case series report. BMC Veterinary Research 18:152. https://doi.org/10.1186/s12917-022-03254-z

Taguchi K and Hyakutake K, 2012. External coaptation of rostral mandibular fractures in calves. Veterinary Record 170:598. https://doi.org/10.1136/vr.100606

Verstraete FJM, 2003. Maxillofacial fractures. In: Textbook of Small Animal Surgery (Slatter D, ed), 3rd Ed, WB Saunders, Philadelphia, USA, pp:2190-2207.

Vogel SR and Anderson DE, 2014. External skeletal fixation of fractures in cattle. Veterinary Clinics of North America: Food Animal Practice 30:127-142. https://doi.org/10.1016/j.cvfa.2013.12.001

Yu Y, Kim N and Heo S, 2020. Application of plate and circumferential wiring with resin to bilateral mandibular fractures in a calf: Case report. Journal of Veterinary Clinics 37:363-366.

Yurdakul İ, 2018. Buzağılarda doğum sırasında ve sonrasında şekillenen kırık olgularının ve sağaltım yöntemlerinin değerlendirilmesi. Harran University Journal of the Faculty of Veterinary Medicine 7:213-218. https://doi.org/10.31196/huvfd.508989

Yurdakul İ, 2023. Evaluation of mandibular fractures formed during birth in calves with acrylic external fixator by clinical and radiographic methods. Journal of Health Sciences Institute 8:237-240. https://doi.org/10.51754/cusbed.1299167

Zimmermann IB, Hässig M and Nuss K, 2022. Unterkieferfrakturen beim Rind: Eine retrospektive Untersuchung von 108 Fällen. Schweizer Archiv für Tierheilkunde 164:609-622. https://doi.org/10.17236/sat00364