Erosion of the medial compartment of the canine elbow: occurrence, diagnosis and currently available treatment options

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Keywords
Elbow, cartilage, arthroscopy, erosion, medial compartment

Summary
Erosion of the medial compartment of the elbow joint refers to full thickness cartilage loss with exposure of the subchondral bone (modified Outerbridge grades 4–5) of the medial part of the humeral condyle (MHC) and the corresponding ulnar contact area. This finding may appear in the absence of an osteochondral fragment or a cartilage flap, or in combination with fragmentation of the medial coronoid process (MCP) or osteochondritis dissecans (OCD) of the MHC.

With regard to the prognosis, it is important to diagnose these severe erosions. Imaging of cartilage lesions by means of radiography, ultrasonography, computed tomography or magnetic resonance imaging is challenging in dogs. In contrast, direct arthroscopic inspection provides detailed information about the cartilage.

The treatment of these severe erosions is difficult because of the limited regenerative capacity of cartilage and presumed mechanical or physical triggering factors. Several conservative and surgical treatment methods have been proposed to treat elbows with severe cartilage defects. However, due to irreversible loss of cartilage, the prognosis in these cases remains guarded.

Introducing...
Erosion of the medial compartment of the canine elbow

Erosion of the medial compartment of the elbow joint is a sign of severe osteoarthritis, since cartilage loss is one of the characteristics of osteoarthritis besides subchondral bone sclerosis, osteophyte and enthesophyte formation and inflammation of the joint capsule (18, 19). Joints affected by severe cartilage damage will often show these osseous changes. However, in some cases clear radiographic signs of pathology are absent, while arthroscopy demonstrates extensive erosions (4). Therefore, severe cartilage erosion of the medial compartment cannot be accurately diagnosed from just the radiographic examination.

The presence of gross cartilage damage of the MCP and the MHC in the absence of an osteochondral fragment has been reported by several authors (1, 3, 4, 20–22). Erosion of the medial compartment occurred as the only pathological finding in six joints in a study reporting the pathological changes found at autopsy of 120 dogs (236 elbows). Histological examination of one of these joints revealed an irregular appearance of the superficial layer and no abnormalities of the deeper layer of the cartilage (20). This form of erosion of the medial compartment seems to occur most frequently in adult and old dogs. In a study describing the arthroscopic findings in the elbow joints of dogs of six years and older, 31% of the dogs showed an extensive erosion of the medial compartment of the joint without a fragmented coronoid process. The presence of only erosions in the control group of young dogs (5–18 months) in the same study was only three percent (4). The exact cause of these cartilage lesions is unknown. Possibly, abnormal forces caused by elbow incongruity, overweight or high activity level may cause abnormal loading of normal or abnormal cartilage resulting in erosion of the medial compartment (3, 4). In the authors’ experience, erosions of lesser severity may also affect the lateral compartment in some dogs.

Erosion of the medial compartment can occur in combination with a fragmented coronoid process, osteochondritis dissecans (OCD), or both together (3, 8). In those cases, the erosions are considered concomitant, to indicate the simultaneous presence of the two elbow lesions without stating that one lesion is the cause or consequence of the other.

The term ‘kissing lesions’ is often used for cartilage erosions of the MHC in combination with a fragmented coronoid process, suggesting that the damage of the MHC is caused by friction from the coronoid lesion (7, 23). Similar cartilage lesions of the MCP were described in joints affected by OCD of the MHC (24, 25). These concomitant erosions were a common finding in studies reporting on the appearance of the joint cartilage at necropsy (20, 24, 25). One study reported deep furrows in some cases and erosions of the radial head in joints with severe osteoarthritis (20). In a study describing the arthroscopic findings in the elbow joints of 263 dogs with disease of the MCP (age 3–135 months), kissing lesions (modified Outerbridge grade >0) were identified in 49% of the elbows. Modified Outerbridge grade 4 and 5 cartilage lesions of the MHC and of the MCP (= erosion of the medial compartment) were identified in 14.4% of the elbows. A more recent theory for concomitant erosion of the medial compartment of the elbow joint states that incongruity might be the cause of cartilage loss. Fragmentation could be the early consequence of elbow incongruity and thereafter erosion of the remaining and more resilient part of the MCP develops with subsequent erosion of the entire medial compartment (3).

Another presentation of erosion of the medial compartment has been described in a study of 35 joints of dogs with recurrent or persistent lameness after arthroscopic treatment of disease of the MCP. In this study, 60% of the joints showed extensive cartilage erosion at the second arthroscopic inspection. Many of those joints initially showed no or mild cartilage damage at the time of the first treatment (26). A similar case was described in a study on complications of elbow arthroscopy (27). To date, it is unclear whether these erosions are the consequence of the original problem or induced by the arthroscopic fragment removal which might leave a degree of instability in the joint.

### Histopathological evaluation of cartilage damage

The modified Outerbridge score is used to quantify cartilage pathology in terms of the depth of the lesions (4). However, cartilage can also be evaluated microscopically using the Mankin histological and histochemical scoring system (28). According to this system, cartilage degeneration was categorized into three stages. Stage I with a Mankin score of 0–6 points, indicates mild degenerative changes. Stage II with a Mankin score of 7–9 points, indicates moderate degenerative changes. Stage III with a Mankin score of 10–14 points, indicates severe degenerative changes (i.e. cartilage disor-

### Table 1 Modified Outerbridge classification system (4).

<table>
<thead>
<tr>
<th>Modified Outerbridge classification</th>
<th>Description of gross cartilage findings</th>
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<tbody>
<tr>
<td>0</td>
<td>Normal cartilage</td>
</tr>
<tr>
<td>1</td>
<td>Chondromalacia (cartilage with softening and swelling)</td>
</tr>
</tbody>
</table>
| 2                                   | Fibrillation 
Superficial erosions with pitting or a ‘cobblestone’ appearance 
Lesions that do not reach subchondral bone |
| 3                                   | Deep ulceration that does not reach the subchondral bone |
| 4                                   | Full thickness cartilage loss with exposure of the subchondral bone |
| 5                                   | Eburnated bone                        |
organization or complete cartilage loss with extensive exposure of subchondral bone) (29). A moderate positive correlation has been demonstrated between the Mankin score and the visual cartilage pathology score of the MCP in 53 canine elbows (28). In this study, elbows with an Outerbridge score 4 had a score of 10.9 ± 0.4 by the Mankin system, equivalent to stage III cartilage degeneration (28).

**Diagnosis**

**History of dogs with erosion of the medial compartment**

Since the combination of elbow dysplasia lesions and 'kissing lesions' is a common finding, the breeds affected by concomitant erosion of the medial compartment are similar to the breeds predisposed for elbow dysplasia (3, 4). In those studies reporting cases with erosion of the medial compartment without concomitant fragmentation of the MCP or OCD, the breed of the dogs is not mentioned. This presentation of erosion of the medial compartment seems to be more common in older dogs but has also been described in young dogs (<1 year) (4, 21). In contrast, concomitant erosion can appear both in young adult dogs and in older dogs, probably depending on the size of the lesion and the chronicity of the problem (8, 21, 26). In a study reporting erosion of the medial compartment as a finding in dogs with recurrent or persistent lameness after arthroscopic treatment of elbow dysplasia, the mean age of the dogs at second presentation was five years (9 months – 11 years). The average time between the first and second presentation was 2.5 years (3 months – 6 years) (26).

**Clinical findings**

Dogs with erosion of the medial compartment are mostly presented with non-specific clinical signs of elbow pathology (4, 8). Most dogs with erosion of the medial compartment demonstrate distinct clinical abnormalities such as severe lameness, a limited range-of-motion, signs of severe pain on elbow manipulation or explicit outward rotation of the affected limb and abduction of the elbow (7). Conversely, it is the authors’ experience that some cases show only mild clinical signs.

**Imaging of cartilage lesions**

The radiographic diagnosis of these erosions in the canine elbow is challenging since only the osseous structures are visualized (30). Sclerosis of the subchondral bone and formation of osteophytes and enthesophytes are typical signs of osteoarthritis that are visible on radiographic examination. In a study of elbow lameness in dogs of six years and older, the degree of radiographic osteoarthritis was significantly correlated to the extent of the cartilage erosions, although severe erosions were also found without the development of osteophytes (4). In some cases collapse of the medial compartment is visible on the craniocaudal view (Figure 1), which suggests the presence of cartilage erosions (30). However, care should be taken when evaluating the joint space in non-weight-bearing views. The limitations of radiography were also confirmed in a study demonstrating histological lesions in

![Figure 1](image1.png)

**Figure 1** A) Craniocaudal radiograph of a normal elbow joint. B) Craniocaudal radiograph of an elbow with erosion of the medial compartment. Severe new bone formation, collapse of the medial compartment of the joint and an irregular delineation of the medial part of the humeral condyle is visible.

![Figure 2](image2.png)

**Figure 2** Computer tomographic images of a sound elbow (left) demonstrating a normal medial joint space (arrow) and an elbow with erosion of the medial compartment (right) demonstrating explicit narrowing of the medial side of the joint space (arrow) and marked new bone formation.
the cartilage of elbows that were scored as radiographically normal (28).

Visualization of bone and cartilage via ultrasound is limited by depth of penetration and ability to clearly distinguish tissue architecture because of the high acoustic impedance of bone (31). One study compared ultrasonographic findings with anatomic and radiographic features of the elbow joint. In this study, the head of the radius and its hyaline cartilage were imaged but it remains unclear whether lesions of the articular surface of the MCP or the MHC can be visualized (32). In a study on the ultrasonographic appearance of osteochondrosis lesions of the canine shoulder, cartilage lesions were visualized in detail by positioning the probe perpendicular to the humeral head (33). This is not possible in the elbow because of the anatomical structure of the joint forcing the MCP opposite to the MCH in tight apposition.

Computed tomography is a routinely applied additional diagnostic technique to identify osseous lesions of the elbow joint (34). Direct imaging of cartilage with CT is not possible since CT cannot differentiate cartilage from other soft tissue structures (Figure 2) (12). Cartilage lesions can be estimated indirectly based on the correlation between osteophyte size seen with CT and the degree of cartilage erosions of the elbow joint seen on arthroscopy (12). Similarly, an irregular radial incisure of the ulna on CT was significantly associated with the arthroscopic identification of cartilage erosions of the MCP. However the absence of those lesions on CT does not preclude erosion of the medial compartment (12). More information about the articular cartilage may be provided with CT-arthrography. In human medicine, CT-arthrography is being used to evaluate articular cartilage in several joints (35, 36). In veterinary medicine, the technique has only been described for the detection of meniscal tears, rupture of the cranial cruciate ligament in the canine stifle joint, or both lesions in combination (37–39).

The gold standard for articular cartilage examination in dogs is arthroscopy, a minimally invasive technique which allows direct inspection of the intra-articular structures (1, 10–12, 27). The colour and surface anatomy of the cartilage can be inspected in detail. Typical lesions seen in joints with erosion of the medial compartment are full thickness cartilage lesions with exposure of subchondral bone, showing linear excoriations in advanced cases (modified Outerbridge grades 3–5) (Table 1) (Figure 3). The cartilage of the lateral part of the humeral condyle mainly remains intact and is sharply delineated from the eroded area, although pathology of the cartilage of the lateral compartment of the elbow joint is occasionally observed (4, 25).

More sensitive diagnostic measures are required to identify those cases with marked cartilage disease and minimal radiographic or computed tomographic pathology. Magnetic resonance imaging (MRI) is regularly used in human medicine to detect osteoarthritic changes. In contrast to human joints, MRI of canine joints is not routinely used to visualize cartilage (40). Due to the low resolution of most currently available MRI devices in veterinary medicine, the opposing thin cartilage layers of the canine elbow cannot be clearly differentiated (41).

**Treatment**

The regenerative capacity of cartilage is limited due to the low cellular mitotic activity of chondrocytes and the lack of direct
vascular supply (13, 42). Treatment of erosion of the medial compartment of the canine elbow is challenging.

Conservative and pharmacologic treatment

 Routinely used treatments for osteoarthritis can be applied to dogs with erosion of the medial compartment, including non-steroidal anti-inflammatory drugs, nutraceuticals, platelet-rich plasma, hyaluronic acid, and pentosan polysulfate sodium (13, 43-45). However, actual evidence that these products have a positive effect on the cartilage lesions in the canine elbow is lacking.

Surgical treatment of erosion of the medial compartment of the canine elbow

 In general, arthroscopy is performed to confirm the diagnosis of erosion of the medial compartment. When observing a concomitant osteochondral fragment of the MCP (Figure 3), it can be removed immediately (7, 18, 46). In an evidence based medicine level 4d study (Table 2) describing the arthroscopic removal of a fragmented MCP as a single treatment in dogs with concomitant severe elbow incongruity (radio-ulnar step >3 mm), some dogs also had modified Outerbridge score 4 cartilage lesions. Despite the cartilage lesions, the dogs had a fair to good long-term outcome. Important limitations of this study included the small number of dogs (n = 8) and the lack of force-plate or motion analysis (46). In addition to fragment removal, several procedures have been described to stimulate spontaneous repair or to induce repair by cartilage transplantation (42, 47-49). However, information is lacking on the long-term results of these techniques.

 As only the cartilage of the medial compartment of the joint is significantly damaged, surgical techniques transferring the load bearing forces towards the healthy lateral compartment have been developed (Table 3 and Table 4).

 One such load bearing transferring technique is the sliding humeral osteotomy (Figure 4). After arthroscopic joint inspection and removal of fragments of the MCP, an osteotomy is performed perpendicular to the long humeral axis and a special sliding humeral osteotomy-plate is fixed to the medial aspect of the humerus causing lateral transposition of the proximal part of the humerus. This lateral transposition results in reduced loading of the medial joint compartment. The technique was evaluated in an evidence based medicine level 4d study involving 59 elbow joints (49 dogs) with severe cartilage lesions and providing medium-term follow-up of 32 joints. Lameness improved in all 32 joints after 26 weeks and resolved in 21/32 joints. Reported complications were a humeral fracture, screw breakage, delayed osteotomy union and minor surgical wound breakdown. Major complications requiring surgical revision were reported in up to 22.2% of the joints (5). More recent preliminary data from the same author demonstrate a reduction of the total complication rate to 4.17% (50). However, another recent evidence based medicine level 4a study involving 32 dogs (35 elbows) treated with a sliding humeral osteotomy reported major complications in 17% of the joints (51). Care should be taken in advising a sliding humeral osteotomy for the management of pain and lameness in case of erosion of the medial compartment. An important concern is the possible development of cartilage lesions in the lateral compartment of the joint after performing sliding humeral osteotomy. Arthroscopic re-evaluation of some dogs several months postoperatively revealed healing of the previously diseased medial joint compartment with fibrocartilage, and did not demonstrate any visible cartilage disease of the lateral compartment (5, 51). Necropsy in one dog 17 months postoperatively revealed a healthy cartilage cover on the lateral part of the humeral condyle with minimal indication of disease (5). Long-term follow-up with force plate analysis of seven dogs demonstrated no significant improvements in limb function in three dogs (51).

 A proximal ulnar osteotomy has been proposed as a method to treat radio-ulnar incongruity, a presumed cause of medial compartment overload. Performing a proximal ulnar osteotomy results in a movement of the proximal ulnar segment which may permit re-distribution of forces along the contact areas of the MCP (52, 53). A recent ex vivo study demonstrated

**Table 2**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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<tbody>
<tr>
<td>1a</td>
<td>Systematic review of randomized controlled trials (RCT)</td>
</tr>
<tr>
<td>1b</td>
<td>Individual RCT</td>
</tr>
<tr>
<td>2a</td>
<td>Systematic review of cohort studies*</td>
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<tr>
<td>2b</td>
<td>Individual cohort study</td>
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<tr>
<td>3a</td>
<td>Systematic review of case-control studies†</td>
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<tr>
<td>3b</td>
<td>Individual case-control study</td>
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<tr>
<td>4a</td>
<td>Lower quality prospective cohort/case control study</td>
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<tr>
<td>4b</td>
<td>Retrospective cohort/case-control study</td>
</tr>
<tr>
<td>4c</td>
<td>Case series – describing outcome for one treatment method with no control group</td>
</tr>
<tr>
<td>4d</td>
<td>Case series – describing novel aspect of management and providing some information regarding outcome</td>
</tr>
<tr>
<td>4e</td>
<td>Lower quality case series – concerns regarding study design and/or ability to interpret information</td>
</tr>
<tr>
<td>5</td>
<td>Expert opinion without explicit critical appraisal, or based on physiology, bench research or &quot;first principles&quot;</td>
</tr>
</tbody>
</table>

*A cohort study is a study that follows a group of patients over a period of time and investigates the effect of a treatment or risk factor.

†A case-control study is one that examines the effect of a risk factor on the outcome for a group of patients with a disease compared to that of a matched control group without the disease.
that proximal ulnar osteotomy is effective in unloading the medial compartment in an incongruent joint (54). A caudoproxi-
mal to craniostial and proximolateral to distomedical oblique osteotomy is recom-
pended to prevent extreme tilting of the proxi-
mal ulnar segment (7, 55). The osteo-
tomy should be located proximal to the
strong interosseous ligament because a distal
ulnar osteotomy will not restore the radio-
ulnar contact areas (52). A favourable clini-
cal outcome after performing a proximal
ulnar osteotomy was reported in dogs with
focal deep cartilage lesions of the MHC,
combined with treatment of the fragmenta-
tion of the MCP (7, 50). Force plate
analysis was performed on 32 elbows at six
weeks, 12 weeks and six months after su-
rgery. A significant improvement in peak
vertical force was measured after six
months (50). Complications were minimal
and included infection, superficial inflam-
ination due to self-trauma, excessive prox-
imal segment migration and seroma. A sec-
ondary surgical intervention was never
required (50). The actual lameness status
was not mentioned in this evidence based
medicine level 5 study and long-term fol-
low-up data were not reported.

An external rotational humeral osteo-
tomy has been described as a technique
with a potential beneficial effect in dogs
with severe erosion of the medial compart-
ment of the elbow (14). This technique was
only evaluated in a cadaveric study, proving
a lateral shift of the peak pressure location
and the centre of pressure, and thus reduc-
ing the pressure acting on the ulna. How-
ever, the orientation of the effective loading
axis depends on the positioning of the leg
during weight-bearing, so clinical trials are
required to investigate the load shift after
external rotational humeral osteotomy and
to evaluate the efficacy of the technique for
treating erosion of the medial elbow com-
partment (14).

Another technique developed to unload
the medial side of the canine elbow joint is
the proximal abduction ulnar osteotomy. A
transverse ulnar osteotomy is performed and
fixed with a proximal abducting ulnar
osteotomy plate\textsuperscript{a} with a step of 2 or 3 mm (\textsuperscript{─}Figure 4). In an evidence based medicine level 5 study involving 36 dogs with high grade cartilage erosions, complications were registered in four dogs, all involving screw breakage or loosening. Half the dogs were presented for re-examination after more than five months and 73\% of these were sound (15). No peer-reviewed studies of this technique are available at the moment and concerns are similar to those for the other load transferring techniques: the risk of creating cartilage damage in the lateral compartment and the lack of long-term follow-up studies using objective measuring techniques.

A proximal ulnar rotational osteotomy, consisting of a transverse osteotomy with 30\textdegree{} external rotation of the proximal segment, is also a technique that shifts contact pressures towards the lateral elbow compartment. An \textit{ex vivo} study demonstrated a significant decrease in contact pressure in the medial compartment and an increased pressure in the lateral compartment, but it is unknown whether this procedure would be efficacious \textit{in vivo} (56).

Total elbow replacement and unicompartmental elbow arthroplasty are other approaches to treating erosion of the medial compartment (\textsuperscript{─}Table 3 and \textsuperscript{─}Table 4).

The first two total elbow replacement designs which were recently introduced are the Iowa state\textsuperscript{b} (Conzemius) prosthesis and the TATE\textsuperscript{b} (Acker) prosthesis (17). Both designs consist of a humeral and radio-ulnar component. The Iowa state design is a non-constrained, stemmed and cemented prosthesis while the TATE elbow system is semi-constrained and uses a cementless resurfacing design (16, 17). An \textit{ex vivo} investigation revealed that the TATE arthroplasty system accurately reproduces the sagittal axis of the elbow, which is a critical factor in the success of functional outcome in human elbow arthroplasty. This finding suggests that the TATE arthroplasty might be less predisposed to component loosening, uneven wear and clinical failure (57). Objective data regarding the functional outcome following TATE implantation are

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|c|c|}
\hline
Author & Type of publication & Treatment method & Number of dogs/joints & Evaluation system & Results \\
\hline
Gutbrod and Guerrero, 2012 (14) & Peer-reviewed & ERHO & 8 cadaveric elbows & Digital pressure sensors in sub-chondral osteotomy distal to the elbow joint & Peak pressure location and centre of pressure shifted laterally \\
\hline
Cuddy et al., 2012 (56) & Peer-reviewed & PURO & 12 unpaired cadaveric thoracic limbs & Digital pressure sensors and 3D static elbow poses & Mean and peak contact pressure significantly decreased in medial compartment and increased in lateral compartment \\
\hline
Burton et al., 2013 (57) & Peer-reviewed & TATE \textit{(first generation)} & 5 pairs of cadaveric forelimbs & Kinematic analysis, using reflective markers & No significant difference in orientation of the elbow axis pre- and postoperative or between left and right \\
\hline
Smith et al., 2013 (62) & Peer-reviewed & CUE & 6 pairs of cadaveric forelimbs & Axial compression using a mechanical testing system & No significant difference between implanted and control limbs in supra-physiological load to failure. \\
\hline
\end{tabular}
\caption{Summary of selected references related to \textit{ex vivo} evaluation of surgical treatment methods of erosion of the medial compartment of the canine elbow joint.}
\end{table}

\textsuperscript{a} KYON AG, Zurick, Switzerland \\
\textsuperscript{b} TATE Prosthesis: BioMedtrix, Boonton, NJ, USA

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{image4.png}
\caption{The principles of sliding humeral osteotomy (right) and proximal abduction ulnar osteotomy (left): transfer of load bearing forces from the eroded medial to the healthy lateral compartment of the elbow joint.}
\end{figure}
lacking at this moment but available subjective data (evidence based medicine level 5) suggest an improvement of limb function up to one year after surgery, although mild lameness may persist. This conclusion was based on data obtained from two clinical centres where the TATE prosthesis was implanted in 39 cases (58). An evidence based medicine level 4a study evaluating the short-term outcome after total elbow replacement with the Iowa state design in dogs with severe osteoarthritis led to a satisfactory result in 80% of the dogs (n = 20) (59). The major complication rate for the TATE elbow system is 7.7% with a similar minor complication rate (58). Reported complication rates for the Iowa state design are 10% intra-operative complications and 20% postoperative complications (59). Potential complications of a total elbow replacement are infection, luxation and fracture of the humeral condyle, fracture of the ulna and implant loosening (58, 59). The newest semi-constrained total elbow replacement system is the Sirius prosthesis. The implant consists of a cemented humeral component and a cementless radio-ulnar component that is secured to bone with screws (60). Further information about the clinical outcome and complication rate of this Sirius system is scarce at the moment. More long-term clinical evaluation of the currently available systems is required and further research into the development of new total elbow replacement systems is underway (50).

The canine unicompartmental elbow (CUE®) arthroplasty system replaces parts of the eroded cartilage in the medial compartment of the elbow joint with a synthetic plug on the ulna and a metal implant on the medial aspect of the humerus (60, 61). This unicompartmental technique has some conceptual advantages compared to the total elbow replacement techniques and the load-shifting osteotomies. First, CUE is designed to restore physiologic medial compartment loading as closely as possible. Secondly, CUE still allows supination and pronation of the radius and ulna in contrast to total elbow replacement where a synostosis is created between the radius and ulna. Third, CUE implantation can be done without violation of the collateral ligaments which may decrease the likelihood of post-operative complications such as joint luxation. The CUE also allows several strategies for revision in case of complications (61). Preliminary results from a clinical study (evidence based medicine level 5) involving 22 dogs demonstrate good or acceptable outcome after follow-up of more than six months, based on subjective assessment of lameness (60). An important limitation of the CUE technique is that only a portion of cartilage is resurfaced. If the cartilage of the lateral compartment is also damaged or the area of resurfacing is insufficient, such that bone-on-bone contact still occurs, the dog may suffer persistent pain (61). Also, objective data about the long-term outcome and complication rate of this procedure are lacking.

A recent ex vivo study reported another type of medial compartment elbow arthroplasty system (62). The ulnar component of this medial unicompartmental elbow prosthesis replaces the cartilage of the MCP, the trochlear notch and the medial part of the anconeal process of the ulna, thus replacing a larger area of the cartilage of the medial compartment than the CUE (62). However, no data are available concerning clinical use and outcome of this type of prosthesis.

Elbow arthrodesis is a salvage procedure that has been abandoned by many surgeons since this complicated surgery leaves a substantial mechanical lameness (63). However, in case of failure of other techniques, arthrodesis of the elbow joint might be the only option left (58).

Sensory denervation of the elbow has been proposed as a possible future treatment method for painful degenerated elbow joints. Similar to the hip, denervation of the elbow has been hypothesized to relieve pain. An evidence based medicine level 5 study in four normal dogs demonstrated no sensory or motor deficits of the forelimb after sensory elbow denervation (64). Clinical studies have not been performed so far.

### Prognosis

The prognosis for patients with severe erosion of the medial compartment is guarded because of the limited regeneration capacity of cartilage.

The surgical load bearing transferring techniques are promising treatment methods. Unfortunately, the level of evidence for the success of all these procedures is low. Sufficient information on complication rates and long-term clinical and objective follow-up are still lacking. Also the risk of developing lateral compartment erosions after these procedures has to be examined before routinely applying these techniques.

The prognosis after total elbow replacement is also questionable. Regardless of the design, a major disadvantage of total elbow replacement are the limited revision options in case of failure (17, 62). Unfortunately, amputation of the leg in case of failure is not an option in most dogs, since elbow dysplasia is typically a bilateral problem.

Regardless of the applied therapy, the owners have to be informed accurately about the complication rate and prognosis in order to have realistic expectations.

### Conclusion

Erosion of the medial compartment of the canine elbow is a complex problem which can present as a single lesion or a concomitant condition. Diagnosis is challenging because erosion of the medial compartment does not generate pathognomonic clinical signs and the cartilage cannot be visualized using non-invasive medical techniques. Treatment of the extensive cartilage damage is challenging since the regeneration capacity of cartilage is limited. Despite a variety of therapies the ideal treatment has not yet been developed. Long-term follow-up studies and studies comparing different techniques may prove the value of currently used techniques. In addition, research into the cause of the problem might lead to preventive measures.
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Conflict of interest statement

None of the authors of this paper have a financial or personal relation with other people or organizations that could inappropriately influence the content of the paper.

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