The comparative biomechanics of the reinforced interdental crossover and the Stout loop composite splints for mandibular fracture repair in dogs

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Summary

Objectives:

To describe a new technique, the reinforced interdental crossover composite splint (RIC) for transverse mandibular fracture repair in dogs. This technique will be compared biomechanically with the established reinforced interdental Stout loop composite splint (RIS) technique.

Methods:

Six pairs of mandibles from young adult small breed dogs were used for the study. Osteotomies were created in a standardized fashion and fixed with either RIC or RIS. All composite splint constructs were tested biomechanically with a cantilever bending force, using a single column testing machine at a rate of 2 mm/min. The time of application, amount of composite used, ultimate force, stiffness, total displacement and total energy absorbed during displacement of the cranial mandibular segment were calculated and compared between the two groups.

Results:

No significant difference was found when comparing the time of application of the RIC and the RIS. All implants failed by either composite resin fracture over the region of the osteotomy or by fracture between the 1^{st} and 2^{nd} molar followed by detachment of the resin from the lingual enamel surface of the 1^{st} molar. Differences between the RIC and RIS in force (80.5 N±40.3 and 51.8 N±27.4. respectively) and stiffness (16.2 N/mm±4.4 and 10.1 N/mm±4.1 respectively) were significant (both p=0.03). However differences between the two techniques in displacement and total energy absorbed were not significant.

Clinical Significance:

In experimentally fractured mandibles of young adult dogs there is evidence that the RIC is biomechanically similar to the RIS.

Keywords

composite, dog, interdental wire, mandibular fracture, resin splint

Introduction

Mandibular fractures occur in 1.5-6% of all small animals presented with fractures (1-3). Retrospective studies of mandibular fractures in dogs have identified young adult, small breed dogs as a group at risk for mandibular fractures (4, 5). Mandibular fractures have a higher incidence in the molar region. Specifically, they tend to follow a transverse trajectory and involving the rostral root of the 1^{st} molar tooth (4).

Due to the anatomical differences between long bones and the mandible, additional factors need to be considered whenever surgery is planned, particularly osteosynthesis (11, 21-23).

An important consideration is the presence of the alveolar canal in the ventral third of the mandibular body. It contains the inferior alveolar nerve, the mandibular alveolar artery and the mandibular alveolar vein (19, 24). The mandibular artery provides the main blood supply to the teeth and the alveolar bone. Severance of this artery during trauma makes the bone fragments completely reliant on the surrounding soft tissue for their blood supply (19, 24, 25). Additionally, multiple foramina are present in the mandible. These foramina are located on the rostrolateral (mental foramina) and the caudomedial aspect (mandibular foramen) of the mandibular body and should, like the alveolar canal, be avoided during implant placement (23, 24). Moreover, there is limited soft tissue coverage that will commonly result in intraoral implant exposure postoperatively (26). From a biomechanical point of view, the tension surface of the mandible is located at the alveolar border. The bone stock, and thus, the safe corridors for implant placement in this region are limited, as tooth roots can extend ventromedial for about 45-70% of the mandibular body depth (19, 27). To prevent interference with important anatomical structures it has been recommended to place implants close to the ventral margin, which is not a biomechanically sound choice (21). Furthermore, an accurate anatomical reduction of the fracture is of great importance to avoid postoperative malocclusion (20).

Noninvasive fracture repair techniques provide fracture stabilisation while avoiding several iatrogenic complications inherent to conventional fracture fixation (11). Interdental composite splinting and interdental wiring are examples of noninvasive surgical techniques used to stabilise a fractured mandible. By combining these two noninvasive techniques, also called reinforcement, the construct will provide superior strength in bending as compared to the techniques used alone (7, 11).

Mandibular fracture repair in dogs by means of noninvasive techniques such as interdental wiring also has its impediments. The conical shape teeth in the dog, the wide diastemas between the teeth and the absence of a supragingival neck make interdental wiring technically difficult and the wire prone to dorsal slippage (22, 23). Constant slipping of the wire when using the Stout loop interdental wire pattern can be frustrating and can complicate the fracture stabilisation prior to composite application (22). Although some authors have advised notching of the teeth using a dental burr to prevent wire slippage (20), others have discouraged this as this intervention can lead to rapid calculus build up and periodontitis postoperatively (22).

Application of the interdental wire just below the cento-enamel junction is easily demonstrated on osteology specimens due to the absence of the gingiva, but the application of these techniques is technically demanding in clinical patients (22). Placing the wire subgingivally when using the Stout loop interdental wire pattern in clinical patients will prevent the problem of dorsal slippage but will result in gross interference with the periodontium (22). In the authors' opinion, significant damage to the gingiva also occurs upon removal of interdental wire when placed subgingivally. Other biomechanically similar interdental wiring patterns adapted to canine anatomy, that respect the enamel surface of the teeth and oral soft tissue, and are less prone to dorsal slippage are thus sought after.

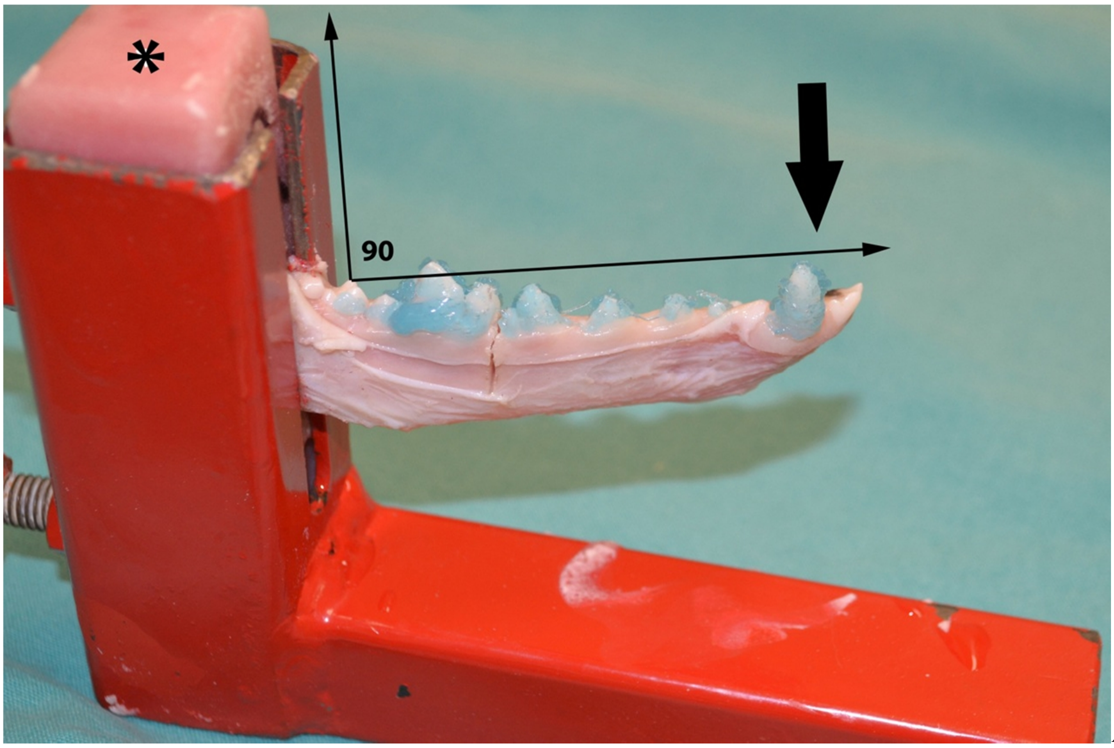
The aim of this study was to introduce a noninvasive mandibular fracture repair technique, the reinforced interdental crossover composite splint (RIC), and to compare this novel technique biomechanically to the reinforced interdental Stout loop composite splint (RIS), in an *in vivo* canine mandible osteotomy model. We hypothesized that the difference between the RIC and RIS techniques for time of application, amount of composite used, ultimate force, stiffness, total displacement and total energy absorbed during testing of the mandible would not be significant.

Materials and Methods

Cadaveric mandibles harvested from 6 client owned small breed dogs (<10 kg) between 6 and 12 months of age were used for the study. All dogs were euthanized for reasons unrelated to this study. The Animal Use and Care Committee of the University of XXX approved the study and owners gave written consent for study and research purposes.

The mandibles were harvested within 12 hours of euthanasia. Initially, they were inspected visually for any crown and eruption pattern abnormalities (including the presence of deciduous teeth). After disarticulation the mandibles were examined radiographically to ensure the absence of fractures, bone pathology and tooth root abnormalities. All the mandibles were stripped of all soft tissue except for the gingiva. During preparation the mandibles were frequently irrigated with 0.9% NaCl[a] to prevent desiccation. Prior to storage, all the teeth were scaled using an ultrasonic scaler[b]. Each pair of mandibles was randomly assigned to one of two groups (group A and B) by the flip of a coin, wrapped in a saline soaked gauze, vacuum-sealed in a plastic bag marked with the patient details and stored at -20°C (28). For mechanical tests, the mandibles were thawed and rehydrated for 5 hours by immersion in room temperature 0.9% NaCl. During preparation and testing the mandibles were constantly irrigated with 0.9% NaCl to prevent desiccation.

A moulding block welded from 2.5 cm square tubing metal was used to imbed the caudal segment (condylar, coronoid and angular processes) of each mandible in a 2.5 cm x 2.5 cm x 9 cm block of polymethylmethacrylate[c]. The condylar and coronoid process of each mandible was kept in contact with the floor of the mould, while the mould was filled with polymethylmethacrylate[c], ensuring that the distance to the surface of the polymethylmethacrylate to the canine teeth was equal for both mandibles of each dog. The mandibles were aligned with the alveolar border perpendicular to the surface of the polymethylmethacrylate and 15 degrees lingually in the sagittal plane (Figure 1). Pre-cut



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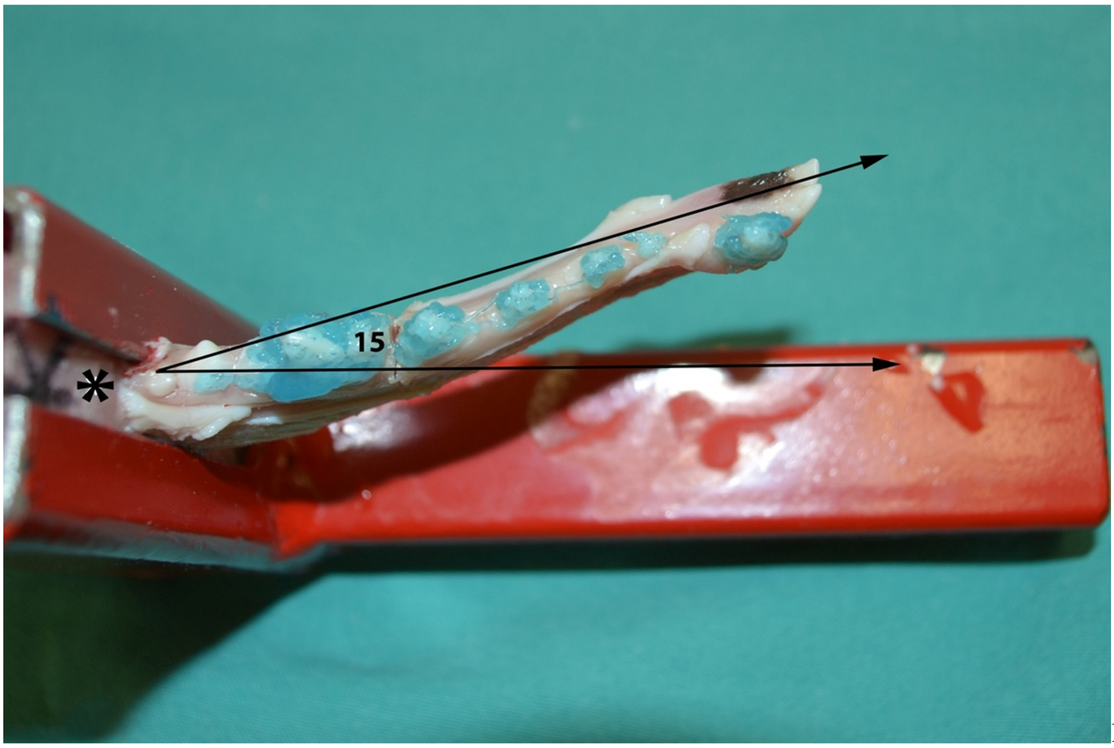

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Fig. 1 The caudal segment of the mandible was fixed in a polymethylmethacrylate block (*) and positioned in a metal mould. The mandibles were position in the polymethylmethacrylate at a 90-degree angle with the horizontal plane (a) and 15-degrees towards the medial plane (b). Note that in both photographs the teeth are covered in 37% phosphoric acid. The black arrow indicates the location and direction of the force during loading.

wooden templates were used to maintain the position of each mandible during polymethylmethacrylate polymerization.

In every bone, a partial osteotomy was created in the diastema between the 4th premolar and the 1st molar using an electric drill[d] fitted with a diamond disc[e] (24 mm diameter and 0.35 mm thick). The osteotomies were made perpendicular to the long axis of the mandibular body and extended from the alveolar margin ventrally for two thirds of the dorsoventral height.

The RIC was applied to the right mandible, whereas the RIS was performed on the left mandible in all patients belonging to group A. The opposite was true for the mandibles in group B.

Prior to application of the interdental wires the teeth were polished using flour pumice and acid etched on both lingual and buccal aspect using 37% phosphoric acid[f]. After 20 seconds the entire etched surface was rinsed with water and air-dried. All the procedures were performed by one investigator (AK), who did not have previous experience in interdental wiring or splinting techniques. The application of the interdental wires was done without contaminating the etched surfaces of the teeth (29).

Reinforced interdental crossover composite splint

For all the mandibular fractures undergoing the RIC, a primer and bonding agent[g] was applied on the buccal aspect (close to the gingival margin) of all teeth from the canine to the 1st molar (excluding the 1st premolar) using a micro brush. The sites of bonding agent application corresponded to the proposed locations of the compomer "buttons" on the buccal aspect of the teeth. The bonding agent was polymerized using a curing light[h] for 10 seconds. A "button" of compomer[i] was placed onto the bonding agent and polymerized for 40 seconds. The function of these "buttons" was to prevent dorsal slippage of the interdental wire (Figure

2). A 0.45 mm stainless steel orthopaedic wire[j] (22) was placed through the diastemas of the 1

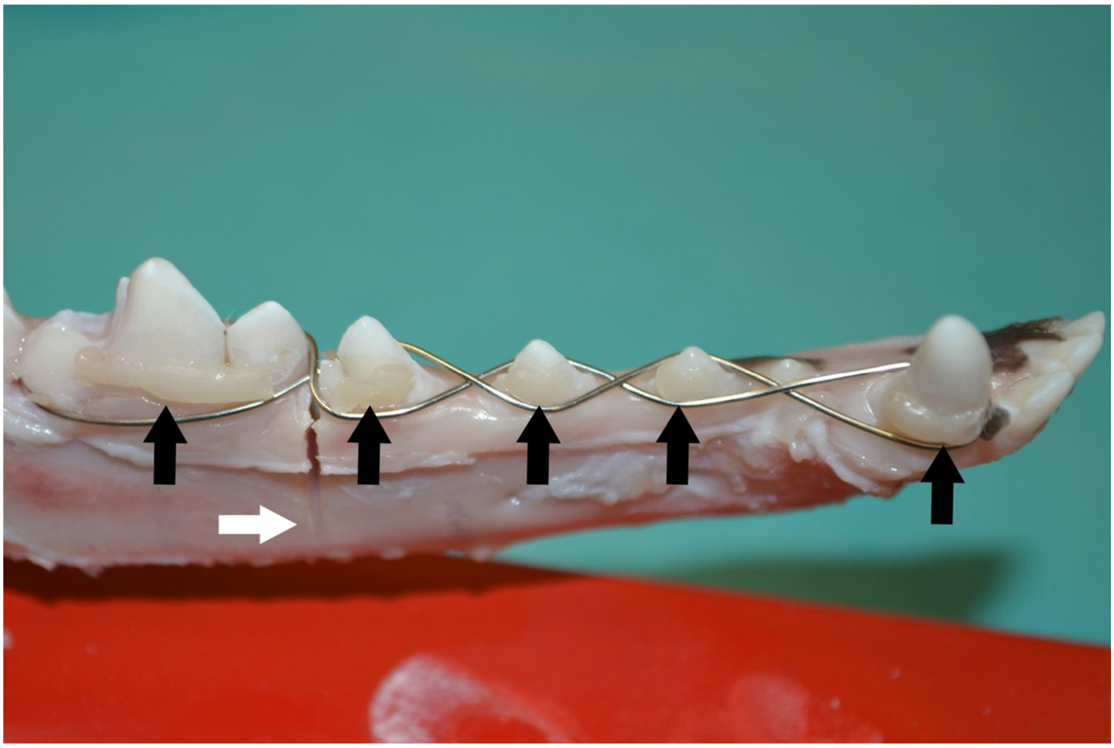

Fig. 2 Reinforced interdental crossover technique before the application of the chemical cure composite resin. Note the small “buttons” of compomer just dorsal to the interdental wire (black arrows). The osteotomy (indicated by the white arrow) has not yet been completed.

st and 2nd molar so that the free ends of the wire extended rostral past the incisors. The wire was then advanced rostrally on the lingual and buccal aspects of the teeth, ventral to the buccal “buttons”, crossing in the diastemas between subsequent teeth, except for the 1st premolar (Figure 2). No attempt was made to consistently pass the buccal or lingual wire either ventral or dorsal in relation to each other. The free ends of the wire were twisted close to the gingival margin of the canine, until the wire was tight, without causing collapse of the osteotomy gap and cut leaving 3 to 4 turns.

A chemical cure composite resin[j] was applied to entirely cover the wire on the lingual and buccal aspects of the teeth from the 1st molar to canine, while only a small amount was applied to the buccal aspect of the 1st molar and the canine teeth. The chemical cure composite resin[k] canister was weighed just before and immediately after the application, and the amount of acrylic used was recorded.

After application the chemical cure composite resin was allowed to polymerize for 5 minutes. The ventral third of the osteotomy was then completed and the mandible immersed in a 0.9% NaCl solution until testing.

The time from the start of each technique until the end of the chemical cure composite resin application was recorded for each mandible.

Reinforced interdental Stout loop composite splint

The technique for application of the interdental wire used in the RIS has been previously described (20, 22). In short, a 20-gauge hypodermic needle was used to assist the passage of a 0.45 mm wire subgingivally in the diastema between the 1st and 2nd molar. One end of the wire was placed along the buccal aspect of the teeth from the 1st molar to the 3rd incisor. The other end was made longer and advanced from the lingual aspect, through the diastema of the 4th premolar and the 1st molar, dorsal to the wire towards the buccal aspect, and then looped back via the same route, ventral to the wire. The loop formed in the diastema on the buccal aspect was twisted clockwise to tighten it (avoiding collapse of the osteotomy gap) (Figure 3). These steps were repeated for each interdental space and ended by twisting the two free ends close to the gingival margin. The ends of the wire were cut leaving 3 to 4 turns.

The application of the chemical cure composite resin was identical to the technique used for the RIC.

Fig. 3 Reinforced interdental Stout loop technique (RIS) before the application of the chemical cure composite resin. The osteotomy (indicated by the white arrow) has not yet been completed. Note the frosted white appearance of the teeth post acid etching.

Biomechanical testing

A custom made jig fixed the polymethylmethacrylate block to a single column testing machine[l] (Figure 1).

During testing a 500 N, S-shaped load transducer[m] (error +/- 0.03% of total load) was mounted to a linear actuator under control of a servovalve (servohydraulic unit). During testing the actuator rod (with the load transducer attached to it) moved downward and exerted a cantilever bending force with the aid of an indenter to the region between the canine and the 3rd incisor teeth. The indenter was custom made from a 12 mm diameter round bar with a 40 degree bevelled and blunted tip.

A dorsoventrally directed force was applied at a rate of 2 mm/min based on methods used in a previous study a previous study (30). A controller unit[n] was used to control the displacement during constant loading.

The resistance of the mandible to the force was measured in Newton (N) using a load transducer. Ventral displacement of the rostral segment (between the canine and the 3rd incisor) was calculated as the displacement of the actuator during testing. Data were recorded at a frequency of 10 Hertz using commercial software[o] and exported into a spreadsheet program[p] for further processing.

All mandibles were tested until failure. The failure point was defined as the point when the interdental wire or the composite fractured or whenever the composite failed by detaching from the tooth surface. Force-displacement curves were constructed for each mandible and the ultimate force (N at the point of failure), stiffness of the construct (N per millimeter of displacement, measured in the linear portion of the force-displacement curve), total displacement (total mm of displacement from start until failure) and total energy absorbed during testing of the mandible (area under the curve) were calculated (Figure 4). The total energy absorbed by the construct was calculated by the sum of the areas by using the trapezoidal rule of numerical integration (31).

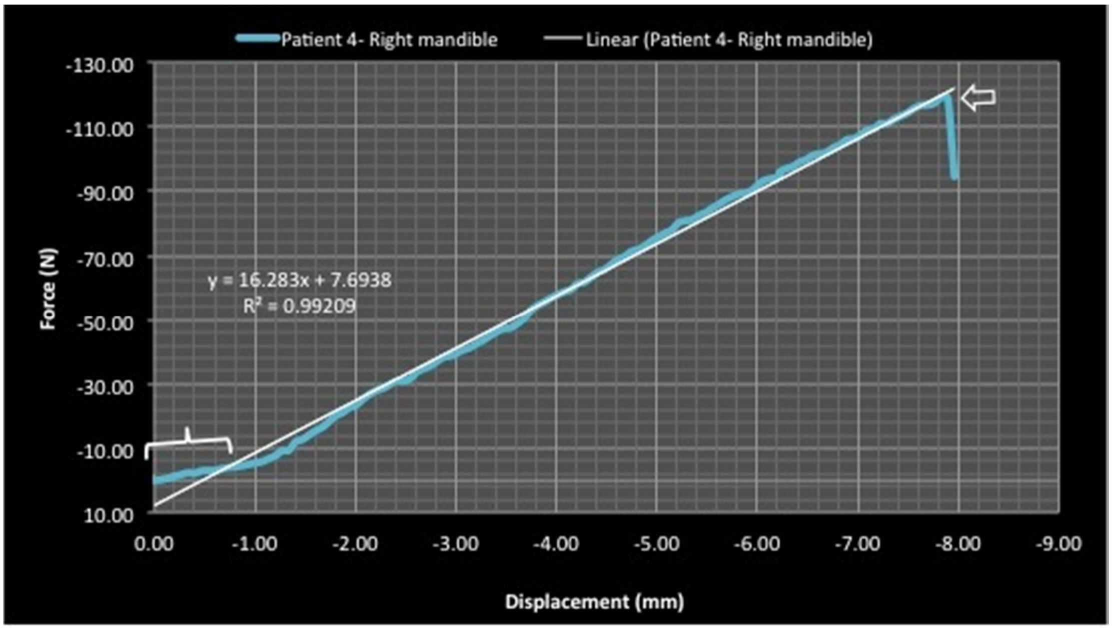

Fig. 4 Force-deformation curve after loading of the rostral mandibular segment at 2 mm/min indicating the phase before the ventral cortices of the mandibular segments made contact (bracket). The black arrow indicates the failure point that corresponded to the ultimate force on the y-axis and the total displacement on the x-axis. The total force absorbed (shaded grey region) was calculated from area under a best-fit trendline (black line).

During cantilever loading in a gap model, a low-stiffness phase can be recognized on the initial part of the force-displacement curve. The initial phase was included in the calculation of the ultimate force, total displacement and the total energy absorbed**.**

Statistical analysis

The Akaike information criterion (32) corrected for finite small samples sizes was used to compare time needed for application of the techniques against combinations of patient sex, breed, weight, and clinician experience (with subsequent applications). The Wilcoxon signed rank test was used to analyse the differences between the RIC and the RIS groups of paired data (time of application, composite weight, ultimate force, stiffness, total displacement and total energy absorbed). The influence of the composite weight on the ultimate force, stiffness and total energy absorbed was tested using the Pearson Correlation test. Values between -0.8

and -1 and +0.8 and +1 were considered strong negative and positive correlations respectively. Mann-Whitney U test was used to determine whether there were statistical significant differences in the ultimate force and the stiffness between the failure patterns. The time of application, amount of chemical cure composite resin and biomechanical variables were expressed as mean±standard deviation. A p value < 0.05 was considered significant.

Results

The breeds of dog from which bones were harvested for our study in the study were Jack Russell terrier (2), crossbreed (2), Dachshund (1) and Maltese (1). Males and females were equally presented and the mean body weight was 5.7 kg (4.2-6.6 kg). The Akaike information criterion indicated, that gaining experience in either technique was the only factor that explained the variance in time between subsequent applications (p=0.01). The time of application for RIC or RIS was not significantly different (p=0.97).

All implants failed by fracturing of the composite over the osteotomy site (RIC=5 and RIS=3) or by fracturing of the composite between the 1st and 2nd molar teeth followed, in the case of the latter, by detachment of the resin from the lingual enamel surface of the 1st molar (RIC=1 and RIS=3) (Figure 5). In the mandibles belonging to the latter group separate points on the force-displacement curve did not represent the fracture and detachment. None of the failure patterns were associated with breakage of the interdental wire. The differences between fracture pattern group for the ultimate force and stiffness were not significant (p=0.80 and p=1.00 respectively). During testing a small amount of buccal rotation of the rostral segment together with dorsal opening of the osteotomy site was noted (Figure 6).

The ultimate force and stiffness were the only two variables that were significantly different between the two techniques (both p=0.03). The mean ultimate force was 80.5 N (±42.3) and 51.8 N (±27.4), whereas the mean stiffness was 16.2 N/mm (±4.4) and 10.1 N/mm (±4.1) for the RIC and RIS, respectively.

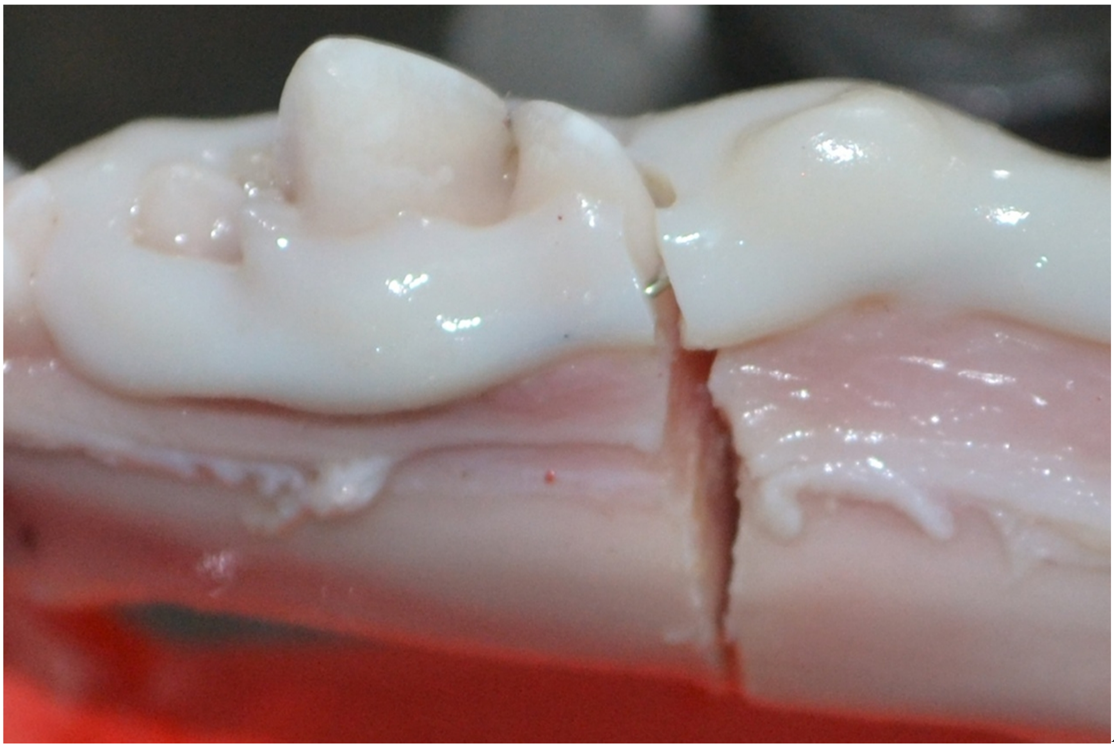

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Fig. 5 Pictures indicating the patterns of failure, either chemical cure composite resin fracture (a) or detachment of the enamel (b). Although not visible in this photograph the imbedded interdental wire was still intact.

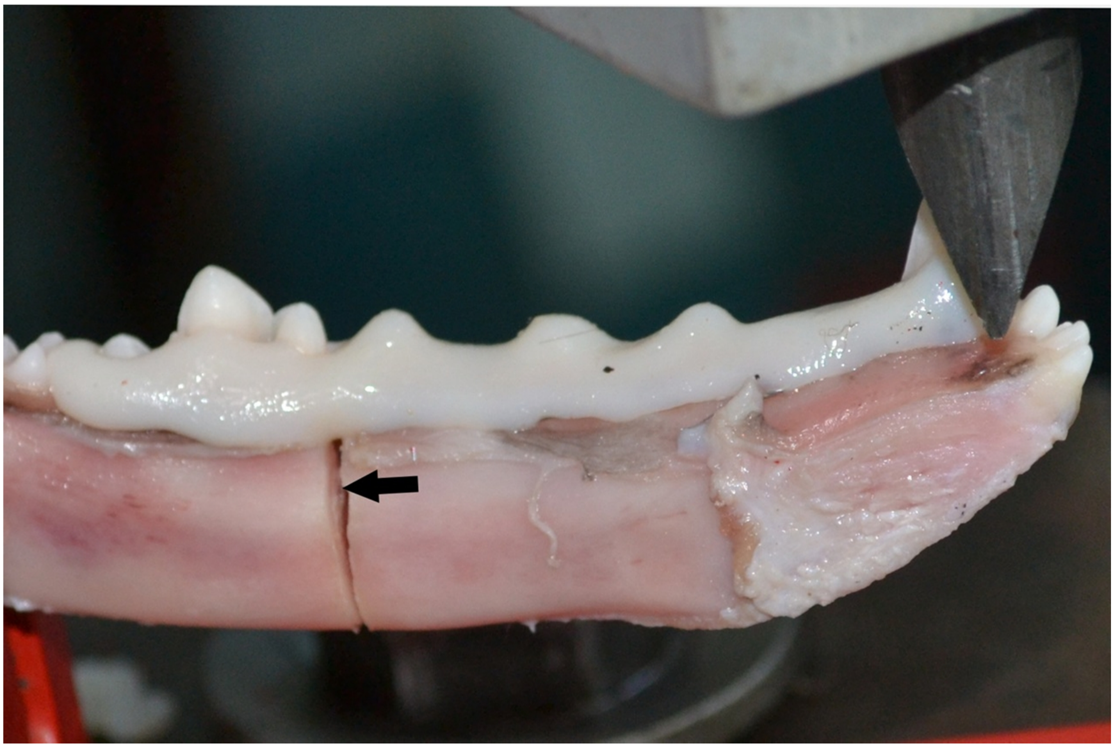

Fig. 6 Photograph showing the lingual aspect of the mandible during testing. Note slight buccal rotation of the rostral segment (black arrow).

During preparation of the model, a small gap was created between the cortices of the rostral and caudal segments. This resulted in low-stiffness phase on the force displacement curve that represents the time taken for soft tissue displacement by the indenter and time until the ventral cortices of the two opposing segments made contact.

The amount of chemical cure composite resin used during application of the two techniques splints was not significantly different (p=0.66). For both the RIC and RIS, there was no correlation between the amount of CCR and the ultimate force (-0.02 and +0.14), stiffness (-0.06 and -0.06) or the total energy absorbed (+0.05 and +0.24).

Discussion

The principle of interdental splinting has been introduced many decades ago to overcome the limitations of the other means of fracture stabilisation of the canine mandible (33). Since then different composites (chemical or light cured) have been used to create intraoral splints in small animals (7, 10, 11, 17, 30). After acid etching, the enamel prism on the surface is demineralized, creating an interlocking retention for restorative and acrylic materials (34). Chemical cure composite resins are mixtures of resins, fillers and coupling agents that are balanced to provide specific physical properties upon mixing, such as flow application and rapid low exothermic polymerization to form the intended structure (29, 35). These products are good choices for interdental splinting and provide more patient benefits when compared to the methacrylate based acrylics (11, 36, 37). The low exothermic temperature reaction (35.6°C) do not results in pulpal damage, as with methacrylate products (36). During application the composite is mixed during extrusion without the generation of any noxious monomer fumes (11, 38). The smooth surface increases the efficiency of plaque removal during brushing, resulting in improved gingival health (35).

The mean ultimate force and stiffness for the RIC specimens were more than 50% that of the RIS specimens. Biomechanically, chemical cure composite resins are considered brittle because they have no well-defined yield point that indicates the transition between the elastic and plastic phases of the material (39, 40). There is in fact a distinct fracture point that coincides with the ultimate force (39, 40). When applying the RIC, compomer buttons were bonded to the enamel surface of the teeth. The bonding agent enhances the shear bonding strength of the compomer (41). This enhanced bonding could potentially contribute to a stronger construct. Acrylics do not adhere well to metal but they do conform to and interdigitate with the wire twists (20). The subgingival course of the wire in the RIS could result in less of the “tensioned” wire being incorporated in the reinforced composite splint, resulting in lesser load to be shared by the interdental wire during the initial phases of testing. Stiffer constructs will undergo a more rapid rise in force with less displacement (42).

Even though the weight and age of the donor animals were very similar in all cases, the anatomy of the mandibles differed quite considerably between different breeds. In addition to this the individual mandibles had no support from the contralateral mandible during testing, dissimilar to the clinical situation. Therefore, a wide range of ultimate forces was encountered for both treatment groups. Factors like a longer distance from the fracture to the applied force (moment arm) and a decrease dorsoventral height of the mandibular body at the fracture location can increase the moment (43, 44). However, neither of these factors correlated with the ultimate force for the RIC or RIS in our study (data not shown).

The amount of CCR used during application did not affect any of the variables and did not differ between the two techniques. An attempt was made to apply enough material to only cover the wire. In clinical cases, excessive CCR will be burred away especially on the buccal aspect of the 1st molar, as it might interfere with the 4th maxillary premolar upon closure of the mouth (11). The authors feel that application of the composite on the buccal aspect of the 1st molar is necessary. This will make the postoperative care more efficient as it decreases the potential for entrapment of food or foreign material like hair between the wire and the teeth. Further studies are warranted to identify whether local removal of CCR at the buccal side has an effect on the biomechanical properties of the interdental composite splints tested in this study.

The time for application was not different between the RIC and the RIS. Although more time was consumed by constructing the "buttons" in the RIC group, this time loss was compensated by the relatively easy application of the interdental wire for the RIC as compared to the more elaborate wire application for the RIS. The strict case selection criteria resulted in the sampling of mandibles that were roughly equal in size creating an almost homogenous population of mandibles, and thus, the time for application was not affected by the body weight of the donors. Throughout this study, expertise in application increased and the time of application decreased for both techniques. In this experimental setting, however, the artificially prepared fracture was uniform for all mandibles. On the contrary, the surgeon in practice, will face different fracture conformations, and often, these will be accompanied by other dental or oral pathology that make the application of the splinting techniques more challenging.

Currently, the optimal procedure for applying interdental wire patterns and composites in canine mandibular fracture repair is still contentious. In the literature, one finds the recommendation to include at least two teeth rostral and two teeth caudal to the fracture site (11). To the authors' knowledge, however, there are no studies evaluating the ideal number of teeth that should be included or whether this number varies according to the anatomical location of the mandibular fracture. For this study, the authors chose to include only one single tooth caudal to the fracture site. The mandibular 1st molar has two roots and a relatively extensive surface area of attachment compared to the premolars and incisors. The teeth rostral to the 1st molar have a conical shape and wide diastemas, and for these reasons, the authors elected to include all the teeth up to the base of the canine around which the wire could be anchored.

Although not specifically evaluated in this study, the 1st molar did not show any visible signs of failing at the time of failure of the composite in any of the tested mandibles. Unfortunately no post testing radiographs were obtained to assess the integrity of the tooth roots and alveoli. Buccal rotation of the rostral segment during testing was probably a direct result of the anatomical shape of the mandible, the absence of the contralateral mandible, the position during testing and the location where the force was applied in these samples. The authors feel that this resulted in more tension on the lingual aspect and could explain the observed failure pattern. It is difficult to judge to what extent rotation of the rostral fragment will occur during loading of a stabilised mandibular fracture in a clinical situation.

The buccal aspect was selected for the compomer "buttons" because it was thought to allow an easier application in clinical patients. Moreover, a "button" on the lingual aspect of the 1st molar tooth will probably provide more resistance against dorsal slippage of the wire during loading and might strengthen the composite enamel bond, besides the clinical advantage of not interfering with full closure of the mouth. However the differences in the ultimate force and stiffness of the constructs that failed by detachment or fracturing of the composite were not significant.

Although the ventral aspects of the cortices made contact early during the loading process, it is uncertain whether this osteotomy gap might affect the performance of the reinforced interdental composite splints during monotonic loading or cyclic loading in clinical patients. To clarify this and to assess whether the placement of "buttons" on the lingual and buccal aspect of the teeth has an effect on the parameters tested in this study, further biomechanical studies would be necessary.

Conclusion

The RIC has been developed to overcome some specific problems related to canine mandibular anatomy. The technique was biomechanically similar to the RIS in the experimental setting used. Further *in vitro* and *in vivo* studies should be conducted to assess whether RIC is a good alternative to the established procedures for mandibular fracture fixation in small animals.

Footnote:

a. *Freeflex saline 0.9%, Fresenius Kabi, Gauteng, South Africa*

b. *Woodpecker UDS-K, Hongtaiyand Dental Instruments Co. Ltd., Guangxi, China*

c. *Polymethylmethacrylate, Melodent dental laboratory, Springs, South Africa*

d. *Dremel, Robert Bosch Tool Co., Racine, Wisconsin, USA*

e. *Dental diamond cutting disc, Rito Dental CO. LTD.,Guangzhou, China*

f. *Best-Etch, Vista Dental Products, Inter-Med INc., Racine, Wisconsin, USA*

g. *Prime and Bond, Dentsply Int. Inc., New York,USA*

h. *LA 500 Blue light, Apoza, Enterprise co. ltd., Taipei, Republic of China (Taiwan)*

i. *Dyract, Dentsply Int. Inc., New York, USA*

j *Orthopaedic wire 0.45 mm/25 G, Veterinary instrumentation, Sheffield, UK*

k. *Protemp 4, 3M ESPE Dental, Seefeld, Germany*

l. *Schenck PM 250, Schenck Ltd., Warwick, UK*

m. *LT400, Loadtech, Gauteng, South Africa*

n. *K7500 Servocontroller, Zwick/Roell, Hauptsitz, Germany*

o. *Matlab R2012a, Mathworks, Natick, Massachusetts, USA*

p. *Excel 2010, Microsoft, Redmond, Washington, United States*

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Appendix Table 1: Patient and biomechanical data of 6 mandibles that underwent biomechanical testing.
RIS = reinforced interdental Stout loop composite splint; RIC = reinforced interdental crossover composite splint; s = seconds; CCR = chemical cure composite resin; g = gram; N = Newtons; N/mm = Newton per millimeter; mm= millimeter; N.mm= Newton millimeter.

Sample number	Technique	Time (s)	CCR (g)	Ultimate force (N)	Stiffness (N/mm)	Total displacement (mm)	Total energy absorbed (N.mm)
1L	RIC	1050	3.5	83.7	18.8	5.0	174.0
2R	RIC	926	3.6	55.4	18.3	3.4	78.1
3R	RIC	929	3.8	139.7	17.9	8.1	629.7
4R	RIC	888	3.9	119.0	16.5	7.9	448.2
5L	RIC	806	3.8	27.6	7.4	3.8	44.7
6R	RIC	759	4.2	57.7	18.3	3.1	91.5
Mean ± standard deviation		**893.0 ± 102.6**	**3.8 ± 0.2**	**80.5 ± 42.3**	**16.2 ± 4.4**	**5.2 ± 2.2**	**244.4 ± 239.1**
Sample number	**Technique**	**Time (s)**	**CCR (g)**	**Ultimate force (N)**	**Stiffness (N/mm)**	**Total displacement (mm)**	**Total energy absorbed (N.mm)**
1R	RIS	1083	3.2	46.3	11,0	5.0	82.9
2L	RIS	1171	3.8	35.3	9,7	4.1	58.2
3L	RIS	976	3.9	94.3	12,1	8.1	437.7
4L	RIS	733	4.0	72.9	15,9	5.7	176.3
5R	RIS	700	3.9	18.1	3,5	5.4	61.8
6L	RIS	735	4.1	43.8	8,4	5.7	119.6
Mean ± standard deviation		**899.7 ± 203.9**	**3.8 ± 0.3**	**51.8 ± 27.4**	**10.1 ± 4.1**	**5.6 ± 1.3**	**156.1 ± 144.8**