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Evaluating the Effect of Resin-Reinforced Fiber Splint Application on the Stabilization of Mandibular Corpus Fractures: An in Vitro Study

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Mandibular Korpus Kırıklarında Rezinle Güçlendirilmiş Fiber Splint Uygulamasının Stabilizasyon Üzerine Etkisinin Araştırılması: İn Vitro Çalışma

ABSTRACT

Objective: This study aimed to evaluate the efficiency of a resin-supported fiber splint in the dental area as a fixation method in order to avoid the disadvantages of using a second plate in mandible corpus fractures

Methods: 24 cadaveric sheep hemimandibulae were randomly divided into four groups. The biomechanical stability of four different groups in which four different fixation methods were applied was evaluated. A single miniplate was used in Group A, and a double miniplate was used in Group B. In Group C, an arch bar was applied along the dental arch with a single mini-plate. In Group D, a single mini-plate was supported by fiber splinting along the dental arch.

Results: The average force values were found at the highest level in the single-plate arch bar group and the lowest in the single-plate group. Looking at the data shown, the single plate arch bar group showed the highest stability, and the single- plate group showed the lowest stability. The mean displacement values were highest in the single-plate arch bar group and lowest in the single-plate group. The aforementioned data coincides with the maximum force values.

Conclusion: It has been noted that the fiber splint application, which was used to avoid the disadvantages of the arch bar application, contributed positively to the stability of fracture fixation.

Keywords: Fracture, Mandible, Fiber Splint

ÖZ

Amaç: Bu çalışmanın amacı, mandibula korpus kırıklarında ikinci bir plak kullanımının dezavantajlarından kaçınmak için, bir fiksasyon yöntemi olarak dental bölgede uygulanan rezin destekli fiber splintin etkinliğini değerlendirmektir.

Yöntemler: 24 kadavra koyun hemimandibulası rastgele 4 gruba ayrıldı. 4 farklı fiksasyon yönteminin uygulandığı 4 farklı grubun biyomekanik stabiliteleri değerlendirildi. Grup A'da tek miniplak, Grup B'de çift mini-plak kullanıldı. Grup C'de tek mini-plak ile dental ark boyunca ark bar uygulanmıştır. D grubunda ise tek bir mini-plak dental ark boyunca fiber splint uygulaması ile desteklenmiştir.

Bulgular: Ortalama kuvvet değerleri tek plakalı arch bar grubunda en yüksek, tek plak grupta ise en düşük seviyede bulunmuştur. Gösterilen verilere bakıldığında, tek plakalı arch bar grubu en yüksek stabiliteyi, tek plaklı grup ise en düşük stabiliteyi göstermiştir. Ortalama yer değiştirme değerleri tek plak arch bar grubunda en yüksek, tek plak grupta ise en düşüktür. Söz konusu veriler maksimum kuvvet değerleri ile örtüşmektedir.

Sonuç: Ark bar uygulamasının dezavantajlarından kaçınmak için kullanılan fiber splint uygulamasının kırık fiksasyonunun stabilitesine olumlu katkı sağladığı kaydedilmiştir..

Anahtar Kelimeler : Fraktür, Mandibula, Fiber Splint

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INTRODUCTION

Maxillofacial complex traumas represent a significant global health concern. Research has demonstrated that the corpus region has a substantial role in mandibular fractures.[1]

There are three forms of closed reduction that are available. The three methods utilized for maxillary fixation are internal maxillary fixation (IMF), external fixation, and splints. The use of IMF has yielded favorable outcomes, assessing fracture stability from a historical standpoint, and is commonly employed. The Erich arch bar is widely regarded as a highly favored instrument in closed reduction methodologies. To such an extent that closed reduction has frequently been used equally with the application of arch bars.[2] The disadvantages of this procedure include increased procedure time, only semi-rigid fixation, difficulty in ensuring oral hygiene, the risk of the surgeon being injured by wires during the procedure, and delayed recovery due to loose wires. Thus, an attempt has been made to develop alternative treatment methods to establish IMF.[3]

On the other hand, surgical treatment with open reduction and internal fixation provides rapid rehabilitation of occlusion, restoration of the anatomical bone morphology, rapid adaptation to social life, and preservation of periodontal tissues. The fixation method with open reduction provides the basic criteria for functional movements of the jaw with acceptable occlusion.[2] However, in mandibular body fractures, fixation with plates and screws is not required for IMF.[4]

At present, it remains unfeasible to advocate for the prioritization of conservative IMF above open reduction in the treatment of adults. Hence, it is imperative to conduct additional clinical investigations with extended periods of observation in adults in order to provide more accurate clinical guidelines for the use of conservative approaches for the management of mandibular fractures.[5]

In the original Champy technique, a single miniplate of 1mm thickness is sufficient for fixation. If a plate is to be placed on the superior border, it is recommended to place an additional plate on the inferior border to neutralize the torque forces.[6] In light of these studies, the researchers concluded that the use of conventional 4-hole plates was an ideal approach to treating mandibular corpus fractures.[6,7] This study aimed to evaluate the efficiency of a resin-supported fiber splint in the dental area as a fixation method, in order to avoid the disadvantages of using a second plate).

METHODS

Preparation of Specimens

The study was carried out on cadaver sheep mandibles. It is a cadaver material obtained commercially (meat-fish institutions, etc.), an ethics committee report is not required. Fresh 12 sheep mandibles that were15-20 months old and fed under similar conditions were obtained for the study. Mandibles were debrided from the surrounding soft tissue and then osteotomized at the midline level between the incisors, and 24 hemimandibles were obtained. The mandibles were preserved at -24 °C until the experiment. 24 hemimandibulae were randomly divided into 4 groups, each group including 6 samples. Osseosynthesis lines were drawn on the hemimandibulae. These points were marked and standardized with a fixed pencil marking the compression (basal region of the mandible) and tension (in the buccal cortex of the external oblique edge) regions defined by Champy. An experimental corpus fracture was created by vertical osteotomy between the premolar and first molar teeth with the help of a resiprocal saw (Figure 1).

Titanium flat miniplates of 1 mm thickness with 4 holes, and 6 mm bars and 2.0 mm diameter screws, 5mm in length were used for all groups (Trimed Titanium Implant System, Ankara, Turkey). The biomechanical stability was evaluated in 4 different groups, in which 4 different fixation methods were applied (Table 1). Miniplates were placed in the compression (mandible basal region) and tension (buccal cortex of the external oblique edge) lines defined by Champy.

Figure 1. An experimental corpus fracture was created by vertical osteotomy between the premolar and first molar teeth with the help of a resiprocal saw

Table1. Fixation Groups

Fixation Groups	
Group A	Single miniplate
Group B	Double miniplates
Group C	Single miniplate + Arch Bar
Group D	Single miniplate + Fiber Splint

Group A: 1 mm thick, 4-hole, 6 mm spaced titanium mini plate (Trimed Medical Co., Ankara, Turkey) and 4 titanium screws 2.0 mm in diameter and 5.0 mm in length (Trimed Medical Co., Turkey) were used.

Group B: Two 1 mm thick, 4-hole, 6 mm spaced titanium mini plates (Trimed Medical Co., Ankara, Turkey) and 8 titanium screws 2.0 mm in diameter and 5.0 mm in length (Trimed Medical Co., Ankara, Turkey) were used.

Grup C: 1.0 mm thick, 4-hole, 6 mm spaced titanium mini plate(Trimed Medical Co., Ankara, Turkey) and 4 titanium screws 2.0 mm in diameter and 5.0 mm in length (Trimed Medical Co., Turkey) were used. In addition, arch bar was applied along the dental arch (B. Braun, Aesculap, Tuttlingen, Germany).

Grup D: 1.0 mm thick, 4-hole, 6 mm spaced titanium mini plate(Trimed Medical

Co., Ankara, Turkey) and 4 titanium screws 2.0 mm in diameter and 5.0 mm in length (Trimed Medical Co., Turkey) were used.

In addition, a fiber splint was applied along the dental arch. The fiber splint was applied to the mandible following the manufacturer's instructions: After cleaning the tooth surfaces, orthophosphoric acid (Vocoid; Voco, Cuxhaven, Germany) was applied to the enamel of each tooth for 30 seconds. The tooth surfaces were sprayed with an air-water spray for 60 seconds. The tooth surfaces were air-dried. A bonding agent (Futurabond U, Voco, Cuxhaven, Germany) was applied to the tooth surfaces with the help of an applicator. The bonding was lightly air-dried. Each tooth surface was cured for 10 seconds with the aid of an LED light device (Valo Cordless, Ultradent, South Jordan, Utah, USA) with an output of 1000 mW/cm2. A 3mm-thick fiber splint (Construct, Kerr Corporation, Orange, CA, USA) was prepared adapted to the dental arch, and the bonding agent was applied. The fiber splint was fixed to the dental arch using flowable composite (Filtek Ultimate; 3M ESPE, St. Paul MN, USA) (Figure 2).

Figure 2. The fiber splint was applied to the mandible following the manufacturer's instructions

Loading Test

After the osteotomy and fixation of the jaws, the specimens were rigidly attached to the INSTRON 8872 servohydraulic tension-pressure testing device (Instron Corp., Norwood MA, USA) by means of a custom fixation device. The experiments were performed at a test speed of 5 mm/min, at room temperature (approximately 21 °C), and under standard atmospheric pressure. BlueHill Materials Testing 2 (Instron Corp., Norwood MA, USA) servohydraulic testing machine software was used to record and graph the resulting displacement and force data. In our study, all subjects were fixed to the experimental setup with the occlusal plane parallel to the ground. The experimental force was applied perpendicularly from the anterior of the fracture line, according to the cantilever beam model, positioning the lever arm at the level of the edentulous bone at the end of the premolars. A preliminary force of 10 N was applied to remove any gaps in the system and to make standard measurements, and then a linear load was applied to the specimens until the plate and screws showed deformation. The maximum force and maximum displacement data were recorded.

Statistical Analysis

IBM SPSS ver. 20 (IBM SPSS Corp., Armonk, NY, USA) was used for statistical analysis. The Kruskal-Wallis test was used to evaluate the difference between groups in terms of maximum strength. To evaluate the difference between groups in detail, pairwise comparisons were made with the Mann-Whitney U test (Table 2).

A homogeneity test was performed to understand the variance distributions of the maximum displacement data, and it was seen that the data were homogeneously distributed. Therefore, the data were analyzed using the one-way analysis of variance (ANOVA) test. Differences between groups were determined using Tukey's post-hoc test (Table 3).

Table 2. Pairwise statistical comparison of groups using the Mann-Whitney U test

Maximum force-pairwise comparison		
Single miniplate	Double miniplates	**0,002**
	Single miniplate + Arch Bar	**0,002**
	Single miniplate + Fiber Splint	**0,002**
Double miniplates	Single miniplate	**0,002**
	Single miniplate + Arch Bar	**0,004**
	Single miniplate + Fiber Splint	0,818
Single miniplate + Arch Bar	Single miniplate	**0,002**
	Double miniplates	**0,004**
	Single miniplate + Fiber Splint	0,065
Single miniplate + Fiber Splint	Single miniplate	**0,002**
	Double miniplates	0,818
	Single miniplate + Arch Bar	0,065

Table 3. Pairwise statistical comparison of groups using Tukey's test

Maximum displacement -pairwise comparison		
Single miniplate	Double miniplates	**0.009**
	Single miniplate + Arch Bar	**0.000**
	Single miniplate + Fiber Splint	**0.003**
Double miniplates	Single miniplate	**0.009**
	Single miniplate + Arch Bar	**0.004**
	Single miniplate + Fiber Splint	0.957
Single miniplate + Arch Bar	Single miniplate	**0.000**
	Double miniplates	**0.004**
	Single miniplate + Fiber Splint	**0.013**
Single miniplate + Fiber Splint	Single miniplate	**0.003**
	Double miniplates	0.957
	Single miniplate + Arch Bar	**0.013**

RESULTS

The displacement and maximum force values of four different fixation methods used in mandibular corpus fractures were converted to digitally recorded graphs.

The average values of all subjects in terms of maximum strength between the groups are shown in Graph 1. The average strength values were found at the highest level in the single-plate arch bar group and the lowest in the single-plate group. Looking at the data shown, the single plate arch bar group showed the highest stability, and the single plate group showed the lowest stability (Figure 3).

The mean values in terms of maximum displacement between all subject groups are shown in the Graph 2. The mean displacement values were highest in the single-plate arch bar group and lowest in the single-plate group. The aforementioned data coincides with the maximum force values. Single plate arch bar group is seen to have required the highest level of strength, and the single plate group has shown deformation at the lowest strength (Figure 4).

The Kruskal-Wallis test was used to evaluate the difference between the groups in terms of maximum strength, and the results showed statistically significant differences between groups ($p<0.05$). Pairwise comparisons were made with the Mann-Whitney U test to evaluate the difference between groups in detail.

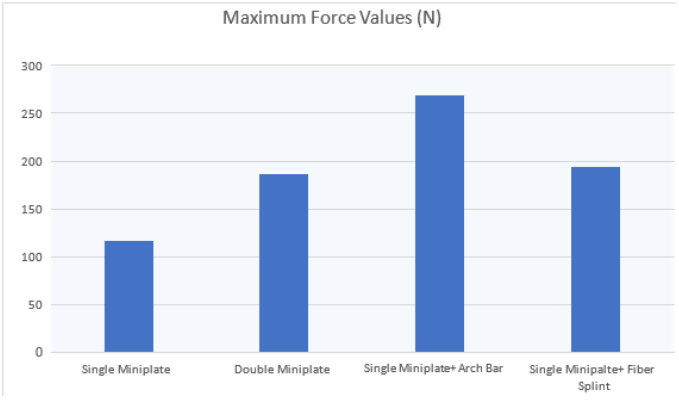

Figure 3. Average maximum force values (N) of fixation groups

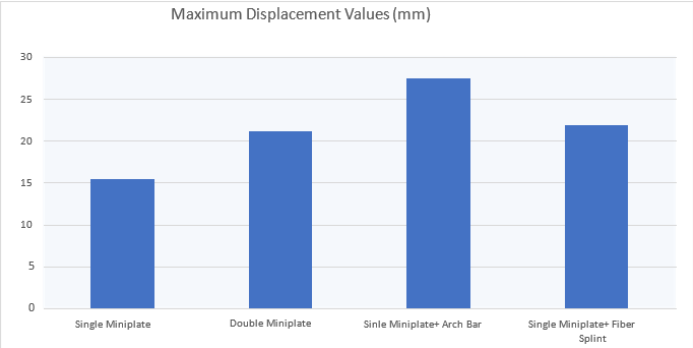

Figure 4. Average maximum displacement values(mm) of fixation groups

Pairwise comparisons were made with the Mann-Whitney U test to evaluate differences between two groups in terms of the maximum strength values in detail. In the evaluation, a statistically significant difference was found between group A and all other groups. Group A showed lower stability in terms of maximum strength required for displacement. Between group A and group B, group B was significantly more stable in terms of maximum strength. Between groups B and C, group C was found to be significantly superior in terms of maximum strength. However, no statistically significant difference was found between groups B and D in terms of maximum strength ($p = 0.818$). Although group C showed higher than average strength values, no statistically significant difference was found between group D and group C ($p = 0.065$).

As the results differed statistically (p 0.001), differences between groups were determined using Tukey's post -hoc test.

In the evaluation, while no statistically significant difference was found between groups B and D in terms of maximum displacement values ($p = 0.957$), there was a statistically significant difference between all other groups.

DISCUSSION

In the context of oral and maxillofacial surgery, plate and screw fixation systems are used in the treatment of facial fractures, orthognathic surgery, and reconstructive surgery.[8] Corpus fractures are one of the most common types of fractures in the mandible.[9] Although mandible fractures are common in the corpus region, in vitro biomechanical studies on this region are scarce. The biomechanical characteristics of rigid fixation systems depend on the interaction between plate, screw, and bone. The ideal in vitro test model should aid in the study of fixation systems in their entirety by providing appropriate physiological and anatomical conditions.[10] In an ideal in vitro test study, the test model that is structurally and morphologically closest to the human mandible should be selected.[11]

In numerous biomechanical studies related to mandible fractures, it has been recommended to use synthetic polyurethane mandible replicas as an ideal study model, as they mimic the cortex and cancellous layers of the mandible and can be standardized in shape, size, and density.[12,13] However, the complex anatomy of the human mandible and the fact that the differing thickness of the cortical bone play a role in the biomechanical behavior of fixation methods. In addition, synthetic mandible replicas pose a disadvantage since they cannot reflect the natural trabecular structure of the bone. Animal-derived mandibles are frequently used in biomechanical studies .[14,15,16] It is advantageous to use sheep-derived mandibles since they most closely resemble the human mandible in shape, structure, and mineralization.[17] Although the cadaveric mandible is the most suitable biomechanical model, certain legal procedures prevent such studies. Models are difficult to store and preserve in suitable environments, and there is a possibility of transmitting infectious diseases from these models.[18,19] Since there is resin-reinforced splint application in the fixation groups in our study, bonding agents must be chemically bonded with the natural dental tissue. For this reason, there was an obligation to perform the study on mandibles of either human or animal origin. Although the most ideal working model would be obtained from cadavers, because of the aforementioned negative aspects, sheep mandibles were used in the study.

In studies conducted after the treatment of mandible fractures, many researchers have reported that masticatory forces are lower than those of healthy individuals.[20,21] He social stated that the patient who was treated for a mandibular fracture could achieve masticatory function utilizing the anterior region rather than the molar region in the first few weeks. In the literature, it is seen that the maximum bite force in the incisal region does not exceed 120 N in the first 6 weeks.[22,23] The study was designed to replicate the bite force from the incisal region, which is in line with the existing literature.

Fibrous and cartilaginous callus formation, which occurs after the inflammatory period in fracture healing takes place over a period of approximately 4 to 6 weeks.[24,25] For this reason, the maximum bite forces occurring in the first six weeks are higher than the maximum force values determined in the biomechanical studies. It should be considered that these fixation methods used in mandible fractures will show insufficient stability.

It is seen that our average maximum strength values in all fixation groups exceeded 115 N. In particular, the single-plate fiber splint group was included as an alternative fixation method, and the average maximum force strength value was determined to be 193 N. Although this value is considerably higher than the maximum bite force values in the anterior region in the literature, it is thought that the single plate fiber splint group can provide sufficient stability in fracture fixation. In the literature, fixation methods differ regarding the treatment of mandibular corpus fractures. Champy claimed that fracture line fixation can be achieved with a single miniplate.[26] However, Arbağ et al.[27] report that the fixation technique applied with two miniplates placed in the compression and tension areas can neutralize the torsion forces and provide better stability. In studies, arch bars have been used to fix fractures in combination with open reduction using miniplates or as a singular treatment as intermaxillary fixation establishing closed reduction.[28,29]

IMF with an arch bar gives good results from a historical perspective when fracture stability is evaluated. The advantages of this procedure are the absence of surgical treatment, the less invasive procedure, the low sensitivity to professional experience to perform the treatment, and the low cost compared to other methods.[30] However, there are also disadvantages such as morbidity, malnutrition, and periodontal disease.[31] Although surgical treatment with open reduction and internal rigid fixation is more invasive than IMF, it has advantages such as anatomical reconstruction of osseous morphology by more efficiently reducing the fracture, rapid adaptation to social life, and preservation of periodontal tissue.[32]

The Erich arch bar is often used as a dental posterior circumdental ligature with wire. Because these wires pass between the teeth, causing periodontal damage, difficulties in maintaining oral hygiene, and orthodontic movements in the anterior teeth emerge. During the operation, the surgeon or the assistant may be at risk of exposure to bloodborne infectious pathogens such as HBV, HCV, and HIV as a result of percutaneous injury from wires.[33,34]

In order to avoid the negative properties of the ligature wire, clinical studies on resin-supported arch bar application devices are being conducted and reported in literatüre.[35,36] It is shown that the resin-supported fiber splint application is used as a stabilization tool during the recovery period in dentoalveolar traumas, especially in cases such as crown and root fractures, luxation, and avulsion of the teeth.[37,38]

When the literature was examined, it could not be determined that resin-supported fiber splint application was used in the treatment of mandible fractures.

Champy et al.[26] analyzed the biodynamics of the mandible with their 2D experimental tests. As a result of these studies, they determined the ideal osteosynthesis lines for the mandible corpus, symphysis. and angulus regions. Fracture healing

However, it is stated that the closer the single miniplate is positioned to the alveolous, the more stability will increase.[27] In cases where a single miniplate is positioned superiorly in mandibular corpus fractures, a more balanced stabilization is provided against the bite forces from the incisal region. Contrarily, positioned on the inferior border, the amount of bending in the plate will increase and the screws will not be loaded equally. Deformation will occur in the system in a short time.[39] Thus, all single miniplates should be placed at the superior border of the osteosynthesis line described by Champy rather than the basal margin of the mandible. In the double miniplate group, the second miniplate was applied to the basal margin of the mandible.

In cases where an IMF is not planned, it may be considered to support the single miniplate with a fiber splint to avoid difficulties in placing the second miniplate. Occlusion was not considered because the study was in the sheep's mandible. In clinical applications, the placement of the splint should be in such a way that it does not prevent occlusion. However, the negative effect to salivary flow in the oral region should be considered when applying fiber splints.

When evaluating if the number of screws, plate type, and thickness are among the contributing factors to stabilization in the studies on corpus fractures, it is seen that the screw diameter is not emphasized much, and monocortical screws with a diameter of 2.0 mm are preferred in most of the studies.[6,8,40]

In our study, we included the use of single and double miniplate groups with 5 mm monocortical screws as an internal fixation method, which are seen as one of the most common and valid treatment methods in isolated mandibular corpus fracture cases. In our study, we used 4-hole 2.0 mm plate and screw systems to achieve a standard in all fixation methods frequently used by maxillofacial surgeons. The findings of our study demonstrated a correlation between the maximum force values and the maximum displacement values, supporting the standardization of the experimental procedure. Nonetheless, no statistically significant difference was observed between the groups treated with fiber splint and double miniplate. The absence of a statistically significant difference between the two groups in relation to maximum strength substantiates this data.

Limitations

There are some limitations to the study. The study fiber splint application was performed on sheep jaws in a moisture-free environment. It should be considered that the adhesive used to perform this application in the oral region in a healthy way is affected by moisture.

The number of subjects was kept minimal due to the difficulties in the supply and storage conditions of sheep jaws. An increasing the number of subjects will make the study more meaningful.

CONCLUSION

It has been noted that the fiber splint application, which was used to avoid the disadvantages of the arch bar application, contributed positively to the stability of fracture fixation. However, single plate can be supported with a fiber splint to avoid the difficulty of a double plate application. The use of fiber splints in fracture fixation should continue to be investigated further in clinical practice.

Etik Komite Onayı: Çalışma kadavra koyun çeneleri üzerinde gerçekleştirildi. Ticari olarak (et-balık kurumları vb.) elde edilen kadavra materyalidir, etik kurul raporu gerekmemektedir.
Hakem Değerlendirmesi: Dış bağımsız.
Yazar Katkıları: Fikir – M.Z.B.; Tasarım – M.Z.B; Denetleme – S.C.K.; Kaynaklar – M.Z.B.; Veri Toplanması ve/veya İşlemesi – E.Y.; Analiz ve/veya Yorum – E.Y.; Literatür Taraması – M.Z.B; Makaleyi Yazan – E.Y.; Eleştirel İnceleme – M.Z.B.
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Ethics Committee Approval: The study was carried out on cadaver sheep mandibles. It is a cadaver material obtained commercially (meat-fish institutions, etc.), an ethics committee report is not required.
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