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Comparison of a novel adhesive system and plate and screw for facial fracture osteosynthesis

Reza Sharifi [1], Mohammad Atai [2], Mahsa Mohajeri [3], Naghmeh Bahrami [4*]

1. Craniomaxillofacial Research Center, Tehran University of Medical Sciences, Tehran, Iran; Department of Oral and Maxillofacial Surgery, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran.

2. Iran Polymer, Petrochemical Institute (IPPI).

3. Department of Prosthodontics, Faculty of Dentistry, Hamadan University of Medical Sciences, Hamadan, Iran.

4. Craniomaxillofacial Research Center, Tehran University of Medical Sciences, Tehran, Iran; Department of Tissue Engineering and Applied Cell Sciences, School of Advanced Technologies in Medicine, Tehran University of Medical Sciences, Tehran, Iran.

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**Corresponding author:*
Naghmeh Bahrami

Craniomaxillofacial Research Center, Tehran University of Medical Sciences, Tehran, Iran.

Tel: +98-21-84902473
Fax: +98-21-84902473
Email: n-bahrami@Sina.tums.ac.ir

ABSTRACT

Background: In oral and maxillofacial fractures, plates and screws routinely fix fragments until the completion of healing process, which has its own complications in some critical fractures. To overcome this drawbacks bone adhesives are developed for the immobilization of fractured bones.

Objective: In this in-vitro study we compared the bond strength obtained by immobilization of the bone fragments using plates and screw and new adhesive containing BTDMA monomer.

Materials and Methods: In this experimental in-vitro trial, bone fractures were simulated in bovine's mandibular bone using an electrical saw. The bone fragments were randomly allocated in different groups and were immobilized with either plate and screws and adhesive containing 0, 10, 15% BTDMA. After 24 hours tensile bond strength was calculated using universal testing machine. One-way ANOVA and Tukey post hoe test were used for statistical analysis.

Results: Mean (±standard deviation) of tensile bond strength of bone fixation using adhesive containing 15% (W/W) BTDMA monomer were 176.0 (±18.89) N. These values were 149.1 (±23.88) N for adhesive containing 10% BTDMA; 102 (±17.99) N for the base adhesive and 278.9 (±24.12) N for the screw and plate technique. Significant differences were found regarding bond strength of bone fixation in 4 groups using bone adhesives or plate technique ($P<0.001$). The highest bond strength was recorded for the plate group and the least was related to the base adhesive. Significant differences existed between all bone adhesives as declared by paired comparison ($p<0.05$).

Conclusion: Despite the lower bond strength in adhesive groups in comparison with screw and plate, with regards to possible complications of screw and plate technique, it seems bone adhesives containing BTDMA monomer can be used for bone fragment fixation. However, bond strength is just one of the numerous properties that an adhesive should have and more studies must be done on these kinds of adhesives.

Keywords: Tensile bond strength; Bone adhesives; Maxillofacial fractures; Plates and screws.

Introduction

The incidence of trauma to the facial region is much more than that of the other parts of the human body. Functional and esthetic problems arise because of the adjoining integral and fragile structures. The conventional treatment for facial fractures is returning the fragments to their primary anatomical position and immobilizing them by using plates and screws until the completion of osteosynthesis and healing process [1].

Although rigid internal fixation with plates and screws is now a widespread method for handling bone fractures, it has its own problems and complications and drawbacks in some critical fracture cases [2,3]. For instance, some of the complications associated with rigid fixation are early or late infection, allergic reaction, loosening of the screw, wound dehiscence and exposure of screws in areas with thin skin or mucosa, artifact production on CT scans (Computed Tomography scan) and MRI (Magnetic Resonance Imaging) studies and thermal sensitivity [2,4,5]. Numerical complications of screw and plates provide a strong incentive to develop an alternative approach to treating bone fractures. Using adhesives as an alternative method to bond split fragments as a substitute for nails and pins.

More than 4000 years ago Egyptiansfirst tried to develop adhesive systems to link divided fragments of bones [6]. Nowadays bioglues are being used in repairing different parts of human body including osteochondral fractures and lacerating tendons and ligaments [7]. Bone fixation is one of the clinical applications of adhesives, which has been reported in some papers [3,8-11]. Midface bonespresent a problem for the adhesion because of their surface structure and inability to eliminate cortical bone in order to improving retention by exposing cancellous bone [4,10]. In the other hand bone represents a hydrophilic nature so that hydrophobic monomers of PMMA base bone cements can not effectively wet bone surface [4], so, more effective bone adhesives are required to achieve adequate bone bond strength. The aim of this study was to compare the bond strength obtained by the immobilization of bone fragments using screw and plate and a new adhesive containing different percentage of BTDMA (3,3',4,4' benzophenone tetra-carboxylic dianhydride methyl methacrylate) monomer, which is some how equivalent to dentin bondings.

Methods and Materials

Titanium miniplates preparation:

Titanium miniplates about 3cm×1cm were prepared and were sandblasted in order to increase micro retention and available surface area for adhesion. Plates were also perforated with some 1mm×1mm holes to achieve macro retention. Bone sample preparation: in this experimental In-vitro study 40 fresh bovine mandibular bone was obtained and bodies of mandible were sawed into slices with 9cm in length in order to equalize samples length. Sections of bones were then disjoint with a band saw to simulate bone fracture and were deep frozen in order to keep them fresh. Specimens were randomly allocated in 4 groups and realigned and immobilized with each of the titanium miniplates and screws (Imen Ijaz, mandible plate 2.0, 4 holes, L.28mm), customized titanium miniplates (3cm×1cm) with 15% (W/W) BTDMA monomer, bone adhesive with 10% BTDMA and adhesive with no additional BTDMA monomer.

Adhesive preparation:

Self cure bone adhesives which was used in this report was an acrylic base adhesive containing Mono (HEMA), Di (Bis-GMA) and three (TMPTMA) acrylate monomers, divided into two parts. First part had peroxide initiator (Benzoyl Peroxide) as catalyzer and the second part has amine as activator. BTDMA monomers (3,3',4,4' benzophenone tetra-carboxylic dianhydride methyl methacrylate) were then added to the base adhesive composition in 10% and 15%(W/W) as initiator.

Plates preparation:

Titanium miniplates with a size of 3cm 1cm were prepared and penetrated with some 1mm holes to increase macro retention and then each plate was sandblasted in order to increase the available surface area for adhesion and micro retention. For the first group, 4 hole plates were manually adapted to conform bone surface. Screw holes were drilled and bone sections were immobilized by using 4 hole plates and screws. For the last 3 groups, periosteum was removed with a periosteum elevator. Bone adhesive was spread onto both bone and miniplates surfaces. Plates were then stored in 9% saline solution with a temperature of 37 for 24 hours in order to let the adhesive set completely.

In-vitro mechanical tests:

After 24 hours a separating force was applied using a universal testing machine (Zwick/Roell Z050). The force was applied perpendicular to the fracture line, at a steady speed of 1mm/min until the fracture occurs in all groups. The force was measured in Newtons. In this study, statistical analysis was carried out using Statistical Package for Social Sciences (SPSS 21.0). Mean failure force, standard deviation, minimum and maximum tensile bond strength in different groups was reported. Repeated measure ANOVA was used to evaluate the results at a 5% level off significance (α=0/05). Differences between the groups were calculated using Tukey standard range test.

Figure 1. After inserting the bone fragment is fixed with screws and plates on the UTM machine.

Results

All specimens were sufficiently were sufficiently stuck and tensile bond strength could be measured in all groups. Mean value and standard deviation of tensile bond strength obtained between bone and screw (group A) was 278.9 (±24.12), bone and 15% BTDMA (group B) was 176.0 (±18.89), bone and 10% BTDMA (group C) was 149.1 (±23.88) and bone and base adhesive (group D) was 102.3 (±17.99) (Table 1). Statistical analysis showed a significant difference in tensile bond strength, which was measured in different groups ($p<0.001$) and the highest value was found for group A (plates and screws) while the lowest was observed in group D.

	N	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Group A	10	176.0000	18.88562	162.4900	189.5100	156.00	216.00
Group B	10	149.1000	23.88142	132.0163	166.1837	118.00	192.00
Group C	10	102.3000	17.99413	89.4278	115.1722	72.00	130.00
Group D	10	278.9000	24.11754	261.6474	296.1526	244.00	310.00

Table 1. Mean value and standard deviation of groups. Bone and screw (group A), Bone and 15% BTDMA (group B) , Bone and 10% BTDMA (group C) and bone and base adhesive (group D).

Group1	Group2	P-Value
Adhesive with monomer BTDMA 15%	Adhesive with monomer BTDMA 10%	0.04
	Adhesive base	≤0.001
	Plate	≤0.001
Adhesive with monomer BTDMA 10%	Adhesive base	≤0.001
	Plate	≤0.001
Adhesive base	Plate	≤0.001

Table 2. Comparison of the two groups of adhesives and plate in terms of the strength of bone fragments fractured with each other.

Discussion

Although rigid fixation with plates and screws is the standard method for bone fixation in maxillofacial fractures, its complications such as foreign body reaction, risk of infection and some other drawbacks made researchers to use bone adhesives instead of this standard method in some critical cases. Perry and Youngson [12] reported that screw fixation isn't an appropriate method for bone immobilization in case of tiny bone spicules presence in midface fractures. Screw exposure or palpability of screws is a real concern in periorbital region because of the thin skin without bulky underlying soft tissue cover [13]. In addition using screws can damage internal organs such as tooth roots, nerves and vessels [2,14].

Bone adhesives contain compositions such as cyanoacrylate; methyl methacrylate, BTDMA and etc. adhesives have some clinical advantages, which make them appropriate if screw fixation is contraindicated. By using these adhesives additional trauma to the bone could be restricted [15,16]. According to the results of this study, maximum tensile bond strength belonged to screw and plate fixation. Adhesive with 15% (W/W) BTDMA placed in second place and adhesive without BTDMA monomer showed minimum tensile bond strength. Despite lower bond strength in adhesives containing BTDMA, tensile bond strength was significantly higher compared with adhesive without the monomer, in addition to this result, bond strength increased with multiplying BTDMA monomer percentage. Ideal tissue and bone adhesives should have some properties such as appropriate bond strength, sufficient working time and setting time, biocompatibility, biodegradability and having no interference with physiological repair process [17,18].

Cyanoacrylates have been used as wound closure material. These adhesives are very moist sensitive and degradation of the glue starts immediately after confronting humidity. Furthermore mechanical qualities of these adhesives are not suitable, to this extent, cyanoacrylates are not apropos as a bone adhesive [19,20]. Fibrin glues, which are used in maxillofacial surgeries, primarily act as hemostatic agent and are generally limited to superficial wounds since they exhibited unsubstantial bond strength. Nevertheless these adhesives are biocompatible and biodegradable [6,21]. PMMA doesn't have any adhesion on it's own as a bone cement but it produce mechanical interlocking by infiltrating into cancellous bone trabeculae [6,11].

Adhesive systems use monomers such as hydroxyl ethyl methacrylate and monomers containing acid in order to improve adhesion between composites and tooth structure [22]. By adding monomers such as HEMA & BTDMA into dentin boundings, carboxylic acid can interact with Ca^{2+} in tooth and bone structure, there for it has the potential to increase bond strength in dental composites and bone adhesives. The reason of using BTDMA in current study is the ability of dimethacrylate monomer in BTDMA, which contain carboxylic acid to interact with ca^{2+} ions of CaO and the ions of hydroxyapatite.It also can induce ionic bond with both metallic plate and bone surface, which is resistant to moisture [23,24]. Maurer et al [25], compared tensile bond strength of three dentin bondings and two cyanoacrylate containing adhesive in an in-vitro study and they concluded that one of the dentin bondings (clearfil new bond) showed higher bond strength (100/56) than other four adhesives. Comparing to current study, clearfil new bond had weaker bond strength than adhesive containing BTDMA monomer. Difference in adhesives, type of bone and size of the samples can justify this diverseness in two studies.

Kandalam et al [26], tested shear bond strength of four adhesives (octyle-cyanoacrylate, N-butyl-cyanoacrylate and a novel cyanoacrylate derivation). Bone samples were immobilized using resorbable plates and adhesive. N-butyl-cyanoacrylate had the most shear bond strength, even more than screw and plates. In current study we measured tensile bond strength while this study tested shear bond strength. More over thy used resorbable plates and screws but we used titanium miniplates. Youngson et al [12] compared bond strength of miniplates and screw and bonded stainless steel plates using cyanoacrylate or dental composite cement. The results showed that miniplates and screws failed at a significantly greater force than adhesives. The results of this research are in line with our study in term of greater bond strength of plates and screws. They also used 4 hole titanium miniplates and sandblasted bonded miniplates. Sandblasting was done in order to increase surface roughness. Results of Meechan et al [27] study showed that surface roughness has positive effect in bond strength between bone, plate and adhesive. It should be noted that comparing the results of various studies is not possible due to different methods of measuring bond strength and different adhesive compositions. More over adhesives containing BTDMA has not been used in researcher related to bone adhesives. Bond strength is just one of the mechanical properties which a bone adhesive should have in order to achieve bone fixation.

Conflict of Interest

There is no conflict of interest to declare.

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