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Biomechanical Stability of Two Different Maxillofacial Screws in a Rabbit Model

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Introduction: Internal rigid fixation techniques are commonly used to treat maxillofacial fractures by stabilizing bone segments using titanium plates and screws. The current study aimed to compare the biomechanical stability of two maxillofacial screws with different tip designs *in vivo*. **Materials and Methods:** Six male rabbits were randomly divided into two experimental periods of 0 and 4 weeks. Under general anesthesia, the screws were randomly placed in the tibia bone on both sides of each animal. The pullout test was conducted using a Sentam test device. Data were statistically analyzed using ANOVA. **Results**: The average insertion torque for non-self-tapping and self-tapping screws amounted to 4.2±1.7 and 4.8±1.4 Newton/centimeter, respectively (P-value >0.05). The calculated measures for the pullout test demonstrated a significant increase of secondary stability after 4 weeks in comparison to 0 week (P-value<0.001). However, the results among the two screws showed no statistically significant difference in each time point (P-value >0.05). **Conclusion:** No significant differences were demonstrated among self-tapping or non-self-tapping maxillofacial screws.

Keywords: Maxillofacial Screws; Rabbit; Pullout Test; Maxillary Impaction; Biomechanics

Introduction

Internal fixation techniques treat maxillofacial fractures and stabilize bone fragments in orthognathic surgeries and bone grafting. The emergence of mandibular osteosynthesis techniques using titanium plates and screws to stabilize bone fragments resulted in considerable progress in treating fractures in maxillofacial surgeries (1, 2). Over a relatively short time period, the rigid fixation was used in orthognathic surgeries as standard treatment due to decreasing the duration of hospitalization and enhancing patient comfort (3). This stability enables the patients to retain their function faster and resume their daily activities in no time (4).

The long-term success of stable fixation depends on reducing movements between bone fragments, sufficient blood flow, and the potential of the host tissue ossification (5). Despite the significant development in designing rigid fixation systems, they may still cause serious complications, *i.e.,* screws may become loose and the bone-screw surface might crack (6-9). Loosen screws might prevent bone fragments from healing and causes infection in the soft tissues (10). Loosen screws expose plates, and they have to be removed early, which results in repeating the operation, increases the costs, and can lead to the discomfort and dissatisfaction of patients (11).

Designing parameters studied in dental implants in various texts include the shape of threads, outer diameter, inner diameter, the length of the implant, cutting threads, thread patterns, thread pitches, implant material, and surface roughness (12). Taking into account the direct impact of screw stability on the results of operation, obtaining quantitative and reliable measurements to manifest the amount and magnitude of this stability is quite crucial (13-16). This study investigated the primary and secondary stability of two screws, commonly used in orthognathic surgeries in Taleghani hospital in Tehran following *in vivo* model.

Materials and Methods

This study was approved by the ethical committee of the School of Dentistry, Shahid Beheshti University of Medical Sciences (IR.SBMU.DRC.REC.1399.089), and carried out in complying with the ethics of animal experimentation after obtaining the approval of the ethics committee to use animals (School of Pharmacy at Tehran University). Therefore, six male rabbits (5 months old and 5.5 kg) were used. The animals underwent a period for experimentation through a light control cycle (12 hours of light and 12 hours of darkness); they consumed water and solid food and were given free residence in a specific environment.

These six rabbits were randomly divided into two experimental periods (0 and 4 weeks). The screws were placed in the Tibia bone on both sides of each animal (Figure 1).
The diameter of screws amounted to 1.2 mm, and their length equaled 9 mm. The pilot hole preparation has remarkable effects on results [17, 18], and all drilling parameters were kept constant during tests. The difference between the screws was in the design of the tip of the screw. The screws manufactured by General Implants company were self-tapping and the screw manufactured by Mondeal company was not self-tapping.

The animals were weighed in terms of their muscles. Then, they were anesthetized using Ketamine. Afterward, antisepsis was carried out using Polyvinylpyrrolidone-iodine (PVP-I) 10% on both the right and left sides of tibia metaphysis. The local anesthesia (Mepivacaine Hydrochloride 2% + adrenaline 1:100000) was applied to contract the peripheral arteries, reduce local bleeding, and optimize the operation procedure. Then, an incision with an approximate length of 5 cm was made using surgical blade No. 15. The muscles were cut to reach the tibia. A cavity with a diameter of 1 mm and a length of 5 mm was made close to the root of the tibia using a special surgical drill of the company. One of two screws was implanted randomly on the proximal tibia and its maximum insertion torque was measured. Both screws had a similar surface (sandblast + acid attack + immersed at Isotonic sodium chloride solution 9%) and they were made of the same alloys. After placement of screws, the soft tissues were stitched using absorbable suture thread (Vicryl®, ETHICON) or non-absorbable (Shalon®-Nylon3-0, Shalon Ltda). After the surgery, all animals received one dose of antibiotics (Pentabiótico®, Wyeth- Whitehall Ltd. a), as well as an analgesic (Tramadol Hydrochloride 50 mg/mm) via intramuscular injection. The animals of the first group were euthanized using an excessive amount of anesthetic right after the surgery, and the animals of the second group were euthanized via the same method after four weeks.

The pullout test was conducted using a Sentam test device (Made in Iran, with a maximum force of 1000 Newton). Accordingly, an incision was made on the bone to be placed the fixture of the pullout test then, it was placed inside the designed fixture.

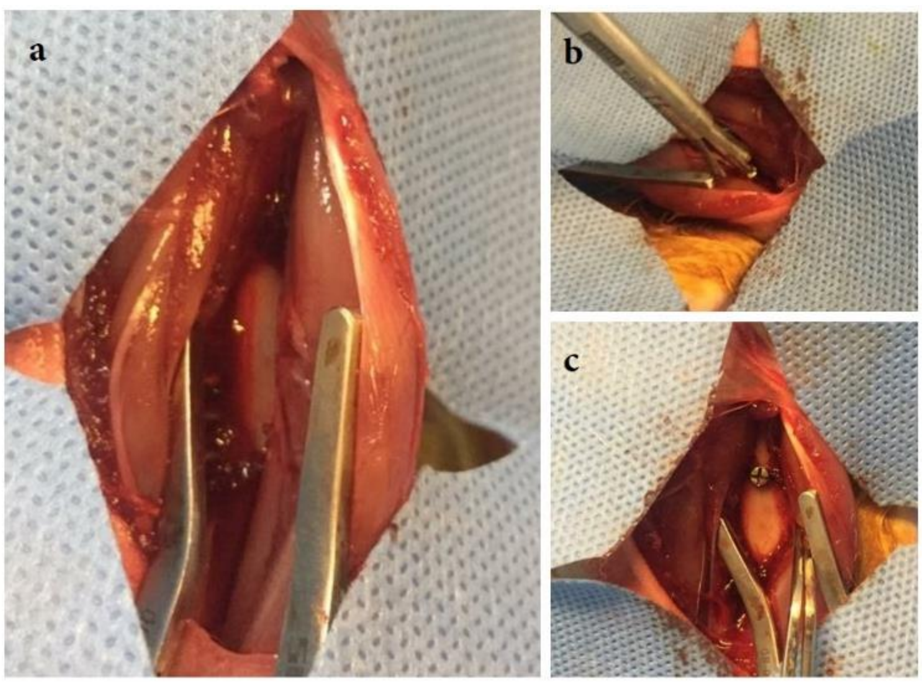

Figure 1. Placement of Screws in tibia of rabbit model

Results

None of the second group rabbits underwent any complications within four weeks. Table 1 shows the results of the screw pullout test of animal samples at zero time (primary stability) and four-week time for two screws with different tip designs.

Table 1. Insertion torque and pullout test results of the screws

Screw	Insertion torque	Stability		*P*-value
		0^{th} week	4^{th} week	
Mondeal	4.2±1.7	102.4±11.8	230.8±32.6	<0.001
General Implants	4.8±1.4	99.8±8.2	214.1±28.3	<0.001
P-value	0.62	0.67	0.50	

The average insertion torque for Mondeal screw (non-self-tapping) and General Implant screw (self-tapping) amounted to 4.2±1.7 and 4.8±1.4 Newton/centimeter, respectively. These two groups of data had no significant difference concerning the results of the ANOVA test. The calculated measures for the pullout test regarding primary stability of screws were 99.8±8.2 and 102.4±11.8 Newton, respectively. There was no significant difference in this regard, either.

To compare the secondary stability, the data of the pullout periods periodsared at two different, i.e.periods, i.e zero and four-week. The significance levels of these data revealed that the required bone solidarity required for the secondary stability was achieved at the fourth week in tibia bone. The levels of significance were approximately the same for both screws, and there was no significant difference between enjoying the self-tapping or lacking this property by screws.

Discussion

Internal rigid fixation of bone fragments is used broadly in ora, and maxillofacial surgeries (2, 19). Its indication and counter-indications have been recognized, and it has a predictable success rate despite several restrictions. The improvement of the fixation systems can increase the success rate of surgeries, reduce the operation duration, reduce the number of used items, and reduce the cost of surgery (20, 21). The use of miniplate and microplates in mandibular bone fragments and medial one-third of the face is proved to be safe.

The most key factor factor in rigid fixation using just screws or screw and plate together is maintaining the consistency of screw threads with the bone (22-24). In addition, the cause of 5% of fixation fractures is the inappropriate choice of screw placement technique (25). Besides, two critical factors in the primary stability of the bone screws include the quality and design ofimplant's surface (26). The bone threading is required when implanting non-self-tapped screws inside the bone after drilling, while, self-tapping screws can be placed directly inside the drilled cavity. The advantage of self-tapping screws includes faster implantation and higher stability in thin cortical bone (27, 28). Drilling is time-consuming and can have potential disadvantages such as injuries to nerves, injuries to teeth root, fracture of the drill, and last but not least, thermal necrosis of surrounding bones. The previous studies suggested that osteolysis of bones surrounding the screw can lead to loss of screw stability (24). Excessive drilling can cause screw fracture in thin cortical bone and lower soft cancellous bone (29).

The use of self-tapping implants dates back to 1983, and they are used in regions with low-quality, bones, such as the maxilla. They need fewer steps when preparing the site for implant placement and the self-tapping implant is inserted inside bones using its drilling force (30). This design can improve the primary stability and, as a result, the success rate of the implant in that region (31). Self-tapping screws follow these rules; they require easier and fewer preparations, reduce the time of surgery, and have a higher success rate (32).

Some studies recommended using self-tapping screws (33, 34); however, other studies reported desirable results regarding non-self-tapping screws (29, 34). Majority of these studies have been carried out on corpses, animals, or artificial skeletal models through pullout analysis. Even though pullout provides beneficial information regarding the power of screw-bone fixation, they can impede collection of sufficient information regarding the internal forces and the stress of the screw-bone contact area.

This study sought to compare two highly used screws in Taleghani hospital of Tehran city. The screws have different designs, i.e., self-tapping and non-self-tapping. This study employed pullout analysis to evaluate the biomechanical power of screws in the tibial bones of rabbits. Pullout power is defined as the maximum power used during the process. Even though the pullout analysis does not evaluate screw fracture in clinical success, it measures the capability of the screw to achieve stable fixation. This method has been argued to be the best method for comparing the power of screws inside bones (35). This study reported that the pullout power of non-self-tapping screws was higher than self-tapping screws during zero and four-week periods. In general, there was no significant difference between these two groups. In the study by Ketata *et al.,* the finite element analysis was used, and the results suggested that the pullout power of self-tapping screws (532 Newton) was more than non-self-tapping screws (432 Newton), and this difference was not significant. These results match the results of the present study [36]. It must be noted that concerning the results of the pullout and incision tests, the self-tapping screws caused more injuries to the bone than the non-self-tapping screws during the placement procedure (36). Ketana *et al.,* demonstrated that even though self-tapping screws enjoyed more manifested during the pullout test, they had less hardness than the non-self-tapping screws. The pullout force is proportionate to the area of contact between screws thread and the bone (29).

Conclusion

The levels of significance were reported to be approximately the same in both screws of the subject of the study and there was no significant difference between self-tapping or non-self-tapping properties of screws.

Conflict of Interest: 'None declared'.

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