Limitations of Current Metallic Bone Plates: towards Development of Composite Bone Plates

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Abstract: Metals remain comprehensively used in orthopedic implants due to their remarkable properties and effectiveness. However, they have certain limitations like metal inappropriateness, corrosion, and stiffness, which, along with other factors, have led to the development of composite bone plates. This study aims to compare the properties of metallic bone plates with composite bone plates and evaluate their effectiveness in various orthopedic applications.

Keywords: Bone plates, composite bone plates, orthopedic implants, composite material.
promote or replace damaged or concerned bones and joints[1]. Orthopedic implants are mainly made from stainless steel and titanium alloys for metropolitan wrinkled with plastic to act as artificial gristle in order to decrease the stress at the enunciating surfaces. Some implants are cemented into place and others are pushed to fit, so that your bone can cultivate into the implant for strength. Some samples of orthopedic implants are: orthopedic plates, orthopaedic nails, and orthopaedic screws. The key issue that guides bone healing is the interfragmentary movement, which regulates the tissue strain and accordingly the cellular response in the breakage healing zone. Thus, the methods of fracture fixation will be evaluated by considering their ability to reduce the interfragmentary movement[10]. To achieve good and acceptable healing results, biomechanical principles should be understood and carefully taken into deliberation.

Bone plate presence used as a method of fracture organization since the late 1800’s. Composure of the fracture using plate requires contact surfaces among implant and bone. The leading metal plate used for fractures fixation showed initial inadequacies such as corrosion, unsatisfactory strength, mansion or nonunion, or a poor return to function. In 1949 recognized the need for compression between the fracture fragments[6]. This achieved by DANIS, using a plate it called the coapteur, which suppressed interfragmentary motion and amplified the immobility of the addiction. It led to a mode of curative he called soudure autogène (autogenous welding), a process now known as primary bone healing. Findings investigations are muscularily encourage developing composite bone plates with biocompatible polymers/fibers that would have modulated properties according to the requirements.

Following are the most commonly used metallic bone plates

2.1. Limited Contact-Dynamic Compression Plate (LC-DCP)

In 1964, A group of Swiss orthopedic surgeons formed the Arbeitsgemeinschaft für osteosyntheseplanungen (AO), also known as the Association for the Study of Internal Fixation (ASIF). The philosophies for breakage management developed by the AO group defined the standard of care for fracture. The Swiss group settled a new plate design intended to decrease the plate’s interference with cortical perfusion and thus reduction cortical porosis. The design was called the limited contact-dynamic compression plate (LC-DCP), which remained claimed to reduce bone-plate contact by about 50%[12].

2.2. Locking Compression Plate (LCP)

Most newly, based on the principle of the point contactor fixator, the locking compression plate (LCP) has been developed Schutz and Sudkamp. The newly advanced, so-called locked internal fixators consist of plate and screw systems where the screws are locked in the plate[6]. This locking reduce the compressive forces exerted by the plate on the bone. Precise anatomical contouring of a plate is no longer essential thanks to these new screws and because the plate does not need to be pressed on to the bone to achieve stability.

3. METALLIC BONE PLATE

The great dependability of metallic materials, in relations of their mechanical performance, has resulted in their use “mainly for the fabrication of medical devices for the replacement of hard tissue such as artificial hip joints, bone plates, and dental implants” [2]. Multiple types of materials and alloys have been investigated in the medical field for their various properties and characteristics [1]. Different alloy systems have been advanced for use in the medical field, including stainless steels, Co alloys, and Ti alloys.

3.1. Ti Alloys

The high biocompatibility of Ti and Ti alloys has occasioned in their privileged use over other alloys systems in the medical and dentistry fields [4]. The primary characteristics of Ti alloys that have resulted in their being one of the main choices in the biomedical field comprise good mechanical properties, excellent corrosion behavior because of a TiO2 solid oxide layer, good biocompatibility, a relatively low Young’s modulus, light weight, and non-magnetic behavior. The aforesaid physiognomies make Ti and Ti alloys the preferred choices for implantation. However, Ti alloys exhibit poor tribological properties because of “low resistance to plastic shearing, low work hardening, and low protection exerted by surface oxides[7].

3.2. Stainless Steels

Stainless steel is extensively used for provisional orthopedic implants such as bone screws, plates and implanted medical devices, besides surgical implements [4]. These materials have high corrosion resistance as they spontaneously form oxides on the surface in various environments.

3.3. Cobalt-Based metals

Cobalt (Co) founded implants have sophisticated wear hostility compared to Ti alloys, which warrants their extensive use in artificial hip joints, where the direct contact between femoral head and the bone or plate over
time may lead to wear. Clinically, Co-Cr-Mo is one of the greatest normally used alloy due to a favorable combination of high strength and high ductility. When compared to cast Co-Cr alloys, wrought Co-Cr alloys that contain Ni, e.g., Co-Ni-Cr-Mo, have higher strength, however since Ni is potentially toxic, it is only used in those applications where this additional strength is required. The elastic modulus of Co-Cr alloys is also higher than that of commercial pure Ti or Ti alloys.

3.4. Zinc Alloys
Currently, zinc compounds are being discovered for bioresorbable metallic stent applications; later most tissues have respectable tolerance to excess Zn ions [10]. Anodic dissolution and cathodic reduction of dissolved oxygen are the main processes involved in the corrosion of Zn, with pH of the surrounding environment playing an important role.

<table>
<thead>
<tr>
<th>Metal and alloys:</th>
<th>Properties</th>
<th>Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Tantalum</td>
<td>-High Strength</td>
<td>- Too hard at tissue contact</td>
</tr>
<tr>
<td>- Stainless steel and Ti alloys</td>
<td>-very stable against gnawing</td>
<td>- easy to corrode</td>
</tr>
<tr>
<td>- Co-Cr (cobalt-chromium) alloys</td>
<td></td>
<td>- high weight and density</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Ions emission may cause allergy in host tissue.</td>
</tr>
</tbody>
</table>

Table 1-2: Tensile strength and Modulus of different metals[5].

<table>
<thead>
<tr>
<th>Material</th>
<th>Modulus(Gpa)</th>
<th>Tensile strength (Mpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless steel</td>
<td>190</td>
<td>586</td>
</tr>
<tr>
<td>Ti-alloy</td>
<td>116</td>
<td>965</td>
</tr>
<tr>
<td>Amalgam</td>
<td>30</td>
<td>58</td>
</tr>
<tr>
<td>Co-Cr alloy</td>
<td>210</td>
<td>1085</td>
</tr>
</tbody>
</table>

Table 1.3 Mechanical properties of some bones[5].

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Modulus(Gpa)</th>
<th>Tensile strength (Mpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortical bone (longitudinal direction)</td>
<td>17.7</td>
<td>133</td>
</tr>
<tr>
<td>Cortical bone (transverse direction)</td>
<td>12.8</td>
<td>52</td>
</tr>
<tr>
<td>Enamel</td>
<td>84.3</td>
<td>10</td>
</tr>
</tbody>
</table>

III. LIMITATIONS OF CURRENT METALLIC BIOMATERIALS

4.1 Stress Shielding Effect
1. The mainstream of the load is approved by the plate rather than by the underlying bone. Callus formation, ossification, and bone union at fractured part are refrained after the implant operation, and the whole bone structure, not only at the fractured part, becomes osteoporosis[14]. The bone mass can be decreased by 20% and in some cases the bone re-fracture due to stress concentration around the bone screws can be induced after the removal of the plate[13]. These phenomena are widely recognized as ‘stress shielding’ effect, which is a main drawback for the use of metal bone plates. As shown in fig 1.

2. The existence of elements such as Ni, Cr, and Co in both stainless steel and Co-Cr alloys has toxic effects [3]. Ni toxicity leads to dermatitis.

3. In addition, 6Al-4V alloy is composed of cytotoxic elements like Al and V, which may cause severe problems once released inside the human body[11].

4. A high friction coefficient and wear debris development can gathering an provocative reaction, leading to thereleasing of implants due to osteolysis [11]. A high modulus of elasticity leads to stress shielding, which reasons implant failure.

5. Fatigue wear often takes place when repetitive, cyclic loading on the implant weakens the surface to producecracks, eventually leading to fragmentation and pitting. Furtherapparel damage caused by these mechanisms include hollows, etches, surface discoloration, surface deposits and third-body particulate
4.2 Biological limitations
1. The longstanding existence of Al and V ions in Ti alloys has been found to cause Alzheimer’s disease, osteomalacia, and neuropathy in the long term [5].
2. The manifestation of Co has also been reported to have carcinogenic effects. Recently, it is reported in that stainless steels and Co-Cr alloys usually contain some harmful elements, such as Ni, Co, and Cr [4].
3. Excessive wear besides rash degradation may negatively affect their biocompatibility, encumber healing and origin long-term impairment [4].
4. When an artificial implant is introduced into a body, protein attachment ensues, followed by a competitive process where host and pathogenic cells attempt to colonize the exterior [14].
5. Tumors generation is rare, though an experiment on Ni grafts in rats saw sarcomas produced at the implant site. Beginning this it was concluded that the potential of tumor growth is connected to the extent of carcinogenic metals allowed to be released into the body [2], as shown in fig 2.

Fig. 2. Comparison of artifacts between metal and composite under X-ray.

IV. NEED OF COMPOSITE MATERIAL

The impression of using composite in bone plate came since 1980. Considering the observed complications and failures from the previous materials, expending composite materials with higher strength and stiffness and further similarity toward natural bone had ongoing to advance. In developed of medical composites, bioactivity is a main factor that must be considered in choosing the material. Polymeric composite material is stable in the body and in vivo condition without any change in strength and stiffness. It can be made of thermoset or thermoplastic composite materials. The main recompenses of composite material over metallic material are as follows.
1. High strength and low modulus.
2. By changing and altering the fraction of reinforcement/matrix phase it is possible to design and make the implants mechanically and physically suitable for different tissues.

3. There is no corrosion like in metal implants.

4. Metals and ceramics can show some failures in X-ray radiography and are not totally radio transparent. But polymeric composites can be transparent by the help of some contrast materials to the polymer.

5. Polymeric composite materials have shown high compatibility with many new diagnosis methods like: MRI because they are not magnetic as the place of computed tomography (CT).

6. Reinforced compounds require more weakness resistance than un-reinforced fusions, which is very central in knee unit addititionally.

V. CONCLUSION

In this review, the presently used metallic biomaterials have been deliberated with possible problems. These tasks currently faced by prevailing implants, and offer biomaterials that not only reduce the likelihood of medical difficulties but possibly offer more ingenuous, inventively assumptions for the patients. Also, numerous inquiries have been exploiting their biocompatibility, bioactivity, biodegradability, besides cellular collaboration.

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