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

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Abstract:*Metals remaincomprehensively used in a erraticism of proposals in the medical field forinternal support and biological tissue exchanges, such as joint replacements, dental roots,orthopedicobsession, and stents.The metallic bone plates have certain complications like metal inappropriateness, corrosion, charisma effect, anode-cathode rejoinders, as well as a decrease in bone mass, increase in bone permeability. also,these plates, made of stainless steel or titanium alloys, tend to shield stress broadcast at the fracture site and interruption the bone healing degree. Therefore, composite materials for bone plates with progressive strength and stiffness and more semblance to natural bone had started to develop. This study examinesboundaries of metallic implants and the probability of acceptingprogressive composite materials to overawed stress shielding effectsto match more carefully to the bone.*

Keywords –*Bone plates, bone plate material, Stress shielding effect,Composite Material.*

I. INTRODUCTION

Over the last some periods, a rise in durability and life confidence has raised the normal stage of the world's populace. This worldwide upsurge in the average age of the population has, in turn, led to a rapidly increasing number of surgical procedures connecting prosthesis implantation, because as the human body ages, the load-bearing joints become more prone to illnesses. This has resulted in acrucial need for upgraded biomaterials and processing technologies for implants, more so for orthopedic and dental applications.

Human joints are multilayered and slight structures capable of functioning under seriouscircumstances, and it is a great challenge for doctors as well as scientists to mature site-specific relocates that can be used in a human body to serve a specific purpose for orthopedic, dental, ophthalmological, cardiovascular, cochlear, and maxillofacial applications[9].Synovial joints such as hips, knees, and shoulders achieve due to the combined efforts of articular gristle, a load-bearing connective tissue covering the bones involved in the joints, and synovial fluid, a nutrient fluid unseenindoors the joint area[12]. However, these joints are more often than not predisposed to to deteriorating and stirring diseases that result in pain and joint difficulty.

The structure of a usual bone is markedly different when related to a bone that is mourning from osteoporosis, with the bone cell density being considerably lower for the osteoporotic bone as associated to the normal bone[9]. The fixtures can be either fixed or removable, which really depends on the type of employed prostheses, a mainstream of which involve complete or partial dentures. In any case, the biomaterial interface and tissue feedback of these implants, lengthways with other intraoral devices, is critical for the stability and sustainability of dental prostheses.

The healing process of bone is a complex process in which both medicine and mechanism are prominently at tragedy and they can alter the time course of the healing development. Interesting to note that all wrecked bones go through the same healing process[8].The bone healing process has three stages: inflammation, bone production soft callus development stage, and hard callus formation stage), and bone restoration. The swelling stage begins the moment the bone is shattered and lasts for around five days. Fortunately, bone has a very good blood supply due to the networks within its structure[1].When a fracture occurs, there is massive disturbance to these blood channels and a large amount of bleeding appears from the fracture wreckages. This is what causes instantbump and bruising in the area of the broken bone. This is known as a Hematoma, which means bleeding inside the tissue. The damaged bone tissue at the edges of the fracture rubbles die back and the dead cells release chemicals called cytokines, which initiate the healing process.This study aims at examining the mechanical assets of the metallic bone plates defining the effect of their length, width and thickness on the properties and compares with the composite bone plates.

II. BONE PLATE

Orthopedic implants cannister be certain as medical devices recycled to replace or offerpetition of bone, or to changepronouncing surfaces of a joint. In simpler words, orthopedic implants are used to either promotion orreplace damaged or concerned bones and joints[1].Orthopedic implants are mainly made from stainless steel and titanium alloys for métierthenwrinkled 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: orthopedicplates, 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 standspresence 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.Theleading 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 muscularly 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 fur osteosynthesefragen (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 greatdependability of metallic materials, in relations of their mechanical performance, has resulted intheir use "mainly for the fabrication of medical devices for the replacement of hard tissue such as artificialhip joints, bone plates, and dental implants" [2]. Multiple types of materials and alloys have been investigatedhipthe medical field for their various properties and characteristics [1]. Different alloy systemshave beenadvancedfor 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 alloysystems in the medical and dentistry fields [4]. The primary characteristics of Ti alloys that haveresulted in their being one of the main choices in the biomedical field comprise good mechanicalproperties, 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 aforesaidphysiognomies make Ti and Ti alloys the preferred choices for implantation. However, Ti alloys exhibitpoor tribological properties because of "low resistance to plastic shearing, low work hardening, andlow 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 materialshave high corrosion resistance as they spontaneously form oxides on the surface in variousenvironments.

3.3. Cobalt-Based metals

Cobalt (Co) founded implants have sophisticated wear hostility compared to Ti alloys, which warrants their extensiveuse 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 greatestnormally 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 bioresorb able 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 1-1: Groups of Metals and their properties[5]

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

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

Material	Modulus(Gpa)	Tensile strength (Mpa)
Stainless steel	190	586
Ti-alloy	116	965
Amalgam	30	58
Co-Cr alloy	210	1085

Table 1.3 Mechanical properties of some bones[5].

Tissue	Modulus(Gpa)	Tensile strength (Mpa)
Corticalbone(longitudinal direction)	17.7	133
Cortical bone (transverse direction)	12.8	52
Enamel	84.3	10

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. Theexistence of elements such as Ni, Cr, and Co in both stainless steel and Co-Cr alloys has toxiceffects [3]. Ni toxicity leads to dermatitis.

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

4. A high friction coefficient and wear debris developmentcaningathering an provocative reaction,leading to thereleasing of implants due to osteolysis [11]. A high modulus of elasticity leads to stressshielding, 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 mechanismsinclude hollows, etches, surface discoloration, surface deposits and third-body particulate

compeers[8]. Thefourth mechanism is tribechemical;interplay of mechanical and corrosive wear, caused by mechanicalactivation of the body's surrounding fluids[2].

6. Stress corrosion cracks (SCC) then spread around the lowest point from cyclic stresses, resulting in fractures [3].

7. Corrosion this oneispositioned an electrochemical reaction on the metal's superficial, with the bodily fluids acting as theelectrolyte. Two reactions befall for corrosion to take place: first is oxidation of the metal surface via removal ofelectrons and additional is reduction of the oxidizing agents which consumes electrons; both processes altermaterial properties [11].

8. Current bone repair implants for use within the body are made since metals, which obligation ddisadvantages such as stress shielding [13].

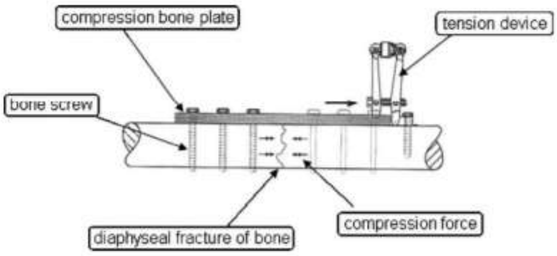

Fig. 1. Schematic of a compression bone plate with a tension device. A compression plate is attached on tensile side of the fragmented bone. Tension device is pulling a compression plate and compression force is accordingly generated at the damaged bones [1].

4.2 Biological limitations

1. The longstanding existence of Al and V ions in Ti alloys hasbeen found to cause Alzheimer's disease,osteomalacia, and neuropathy in the long term [5].

2. Themanifestation 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 andorigin long-term impairment [4].

4. When an artificial implant is introduced into a body, protein attachment ensues, followed by a competitiveprocess where host and pathogenic cells attempt to colonies the exterior [14].

5.Tumors generation is rare, though an experiment on Ni grafts in rats saw sarcomas produced at theimplant-site. Beginning this it was concluded that the potential of tumor growth is connected to the extent ofcarcinogenic metals allowed to be released into the body[2].as shown in fig 2.

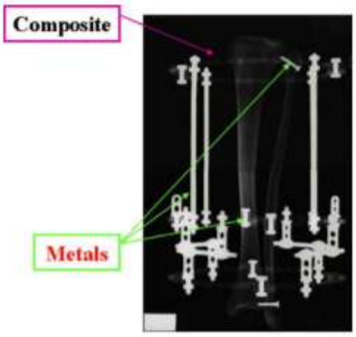

Fig. 2. Comparison of artifacts between metal and composite under X-ray.

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 designand 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 materialto the polymer.
5. Polymeric composite materials have shown high compatibility with many new diagnosis methods like: MRI because they are not magnetic as fitin place of computed tomography(CT).
6. Reinforced compoundsrequire more weakness resistance than un-reinforced fusions,which is very central in knee unitedadditional.

V. CONCLUSION

In this review, the presently used metallic biomaterials have been deliberated with possible problems. these tasks currently faced by prevailinginserts, and offer biomaterials that not only reduce the likelihood of medical difficulties but possibly offer more ingenuous, inventivelyfairassumptions for the patients.Also, numerousinquiries have beenexploit their biocompatibility, bioactivity, biodegradability, besides cellular collaboration.

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