Trakia Journal of Sciences, Vol. 8, Suppl. 2, pp 119-125, 2010
Copyright © 2009 Trakia University
Available online at:
http://www.uni-sz.bg

ISSN 1313-7050 (print)
ISSN 1313-3551 (online)

SOME BIOCOMPATIBLE MATERIALS USED IN MEDICAL PRACTICE

D. Mihov*, B. Katerska

Faculty of Medicine, Medical University of Sofia, Bulgaria

ABSTRACT
A review of some biocompatible materials, widely used in modern medical practice is presented. A concise analysis of the physical properties of the most biocompatible metal, titanium and its alloys is made. The process of vascular stent implantation and its importance for the development of invasive cardiology are presented in details. A classification of contact lenses is suggested. Intraocular artificial implants as a means of cataract treatment are discussed. The most commonly used and most successful dental implants, the osseointegrated titanium screw implants, are presented.

Keywords: titanium implants, vascular stent implantation, intraocular artificial implants.

INTRODUCTION

Biomaterials are artificial or natural materials used in biological systems. Researches in the scope of biomaterials are multidisciplinary and include various aspects of materials science, chemistry, biology and medicine. **Figure 1** illustrates the main types of biomaterials, namely:

Metals: stainless steel, cobalt alloys, titanium alloys

Ceramics: aluminum oxide, zirconia, calcium phosphates

Polymers: silicones, poly (ethylene), poly (vinyl chloride), polyurethanes, polylactides

Natural polymers: collagen, gelatin, elastin, silk, polysaccharide

The broad spectrum of biocompatible materials for use within the human body is shown on **figure 2**. Titanium is considered to be the most biocompatible metal, due to its resistance to body fluid effects, great strength and a low density.

Titanium alloys can have a combination of strength and biocompatibility which makes them suitable for medical applications. Ti-6Al-7Nb has an ultimate tensile strength of about 1000 MPa. Its metallurgy is similar to that of Ti-6Al-4V, with an $\alpha+\beta$ microstructure, but does not contain vanadium to make it more biocompatible. Vanadium oxide (VO_2) generated by passivation is unstable, resulting in a release of vanadium into the body. Niobium is also currently cheaper than vanadium.

Ni-Ti alloys are some of the most reliable shape memory materials. A super-elastic version is used in orthodontic applications. The application of a suitable stress above the martensite-start temperature M_S induces martensite, which in a thermoelastic alloy disappears on the removal of stress. The plastic strain at any stage is completely reversible, giving the effect of large elastic strains (about 8%). This is why the phenomenon is known as *superelasticity*. The alloy can therefore be used like a rubber band as an orthodontic retainer.

Titanium is widely used for implants, surgical instruments and pacemaker boxes. Titanium hip prostheses are well known and have been used for more than 30 years. Contemporary sheaths accelerating titanium adhesion to adjacent bone are already accessible.

Given its biocompatibility and strength, titanium is the ideal material for dental supports and other oral prostheses. The bone adheres naturally to the superficial titanium dioxide layer, thus avoiding the necessity of any additional coating.
This article presents some of the biocompatible materials used in medical practice.

***Correspondence to:** *Dimitar Mihov, Faculty of Medicine, Medical University of Sofia, Bulgaria*

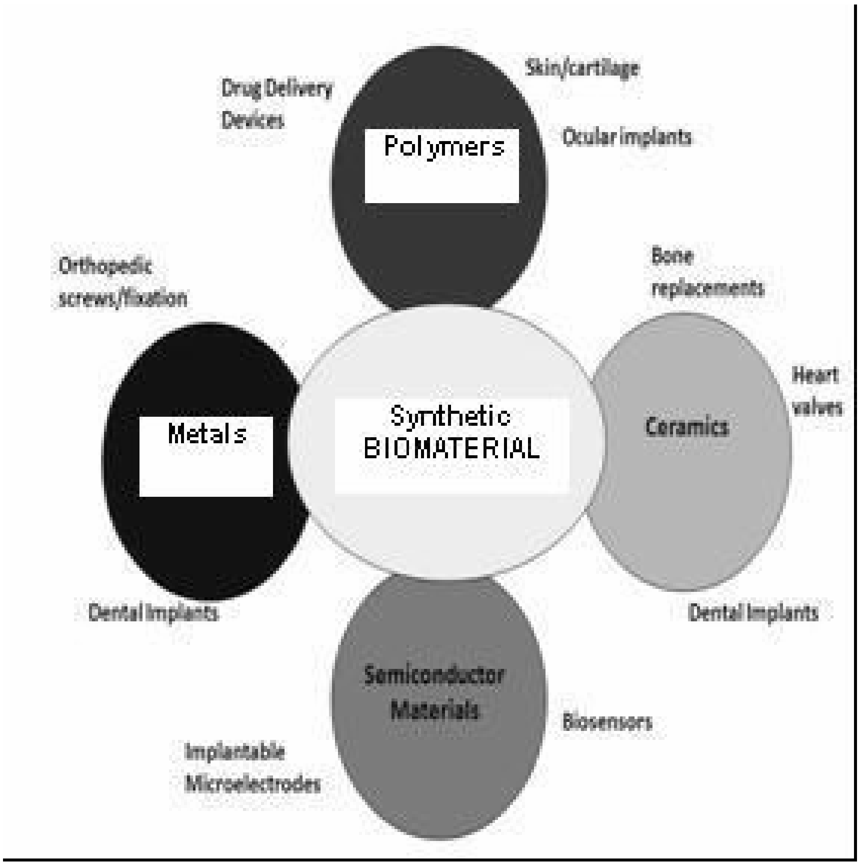

Figure 1. Main types of biomaterials human

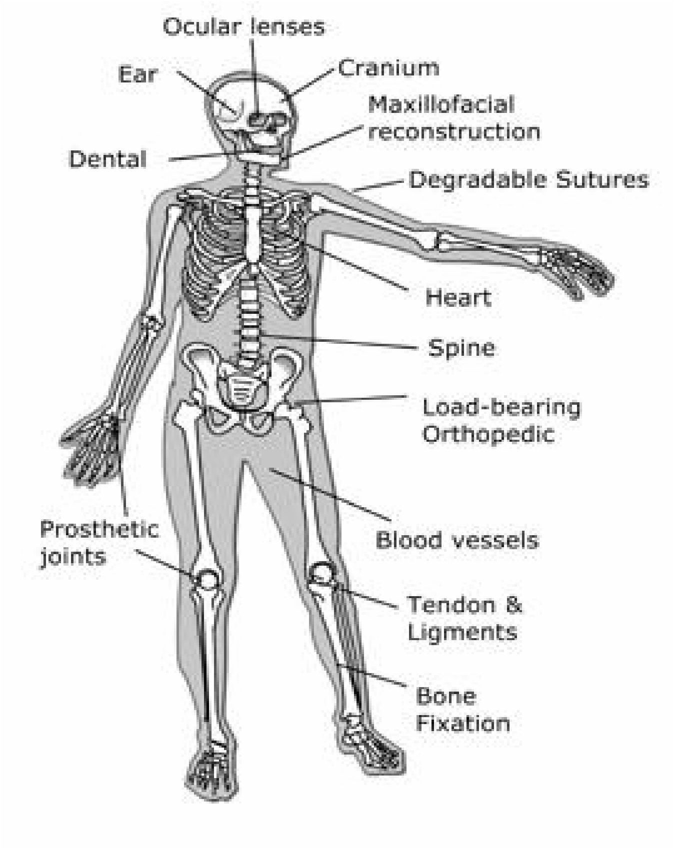

Figure 2. Biocompatible materials in body

1. STENT IMPLANTATION

Stent implantation is a stage in the development of invasive cardiology. The concept of intravascular stent implantation was developed by *Dotter* in 1964, but it was not introduced into practice until 1985, when *Sigwart* implanted the first intravascular stent, a self-expandable Wallstent, in a human iliac artery.

The stent is a miniature metallic mesh **(Figure 3.)**, usually made of stainless steel filaments or recently, of special nickel-titanium or cobalt-chromium alloys, which is mounted on a dilatation balloon and implanted into the dilated arterial site.

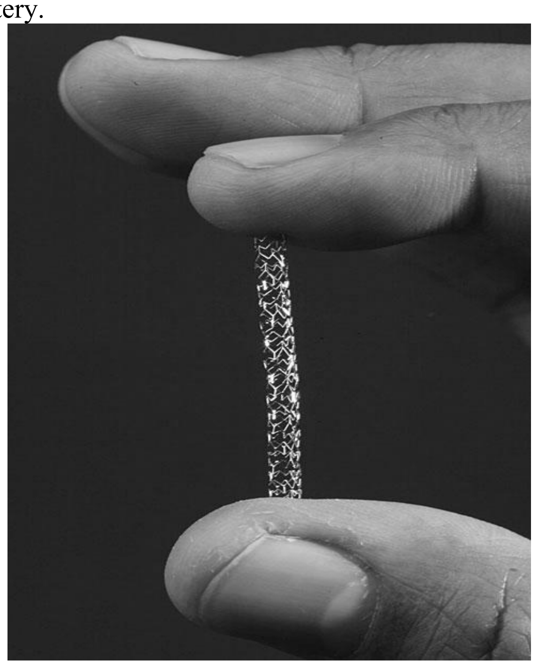

Figure 3. An example of a stent

Routine stent use into practice has significantly reduced the incidence of complications, re-stenosis and repeat revascularisation after coronary angioplasty **(Figure 4)**. A great number of study results, including these from 8- and 10-year follow-ups of patients, have shown the superiority of coronary stent placement over cardiosurgical revascularisation.

However, the tendency to prevalent recurrent complaints and repeat revascularisation is still observed in patients with stents. A possible decision of this problem is the introduction of drug-eluting stents. These are stents, loaded with a specific drug, usually a cytostatic agent, which inhibits the endothelial and fibromuscular excessive proliferation, induced by the presence of a foreign body in the blood vessel. Presently, in the world, as well as in Bulgaria, an increasing number of interventions is performed in other than the coronary arteries – carotid artery stenting, endoaortic prosthesis, laser atherectomy and rotablation, angioplasty of peripheral, visceral and renal arteries, closure of atrioventricular fistulas, vascular embolisation (for example, in tumors of vascular origin), insertion of inferior vena cava filters in cases of pulmonary thromboembolism, superselective fibrinolysis in cases of pulmonary thromboembolism, percutaneous mitral and aortic valvuloplasty, etc.

2. OCULAR LENSES

Contact lenses are the second widespread means for correction of visual disturbances, due to deviations in the ocular optical system (hyperopia, myopia, astigmatism, keratoconus). Contact lenses are also used with cosmetic purposes for accentuating or changing the eye colour (colour contact lenses), protection of the eyes from radiation, enhanced healing of corneal lesions, etc.

Depending on material, there are three main types of contact lenses:

• Rigid lenses from plexiglass (PMMA). These lenses are in fact outdated and are rarely used.
• Soft lenses from gel-like plastic materials. These lenses are a little bit larger than the iris and find the most common application.
• GP lenses, known as rigid gas permeable (RGP) lenses, produced of rigid, hydrophobic plastic materials and recommended in

presbyopia and severe astigmatism. Usually, these lenses have a diameter of about 8mm and are smaller than the iris.

• Silicone-hydrogel lenses, a type of soft contact lenses, known also as "breathing" lenses and produced of a silicone polymer. Silicone-hydrogel lenses are increasingly implemented into practice and are considered to be one of the best achievements in contactology.

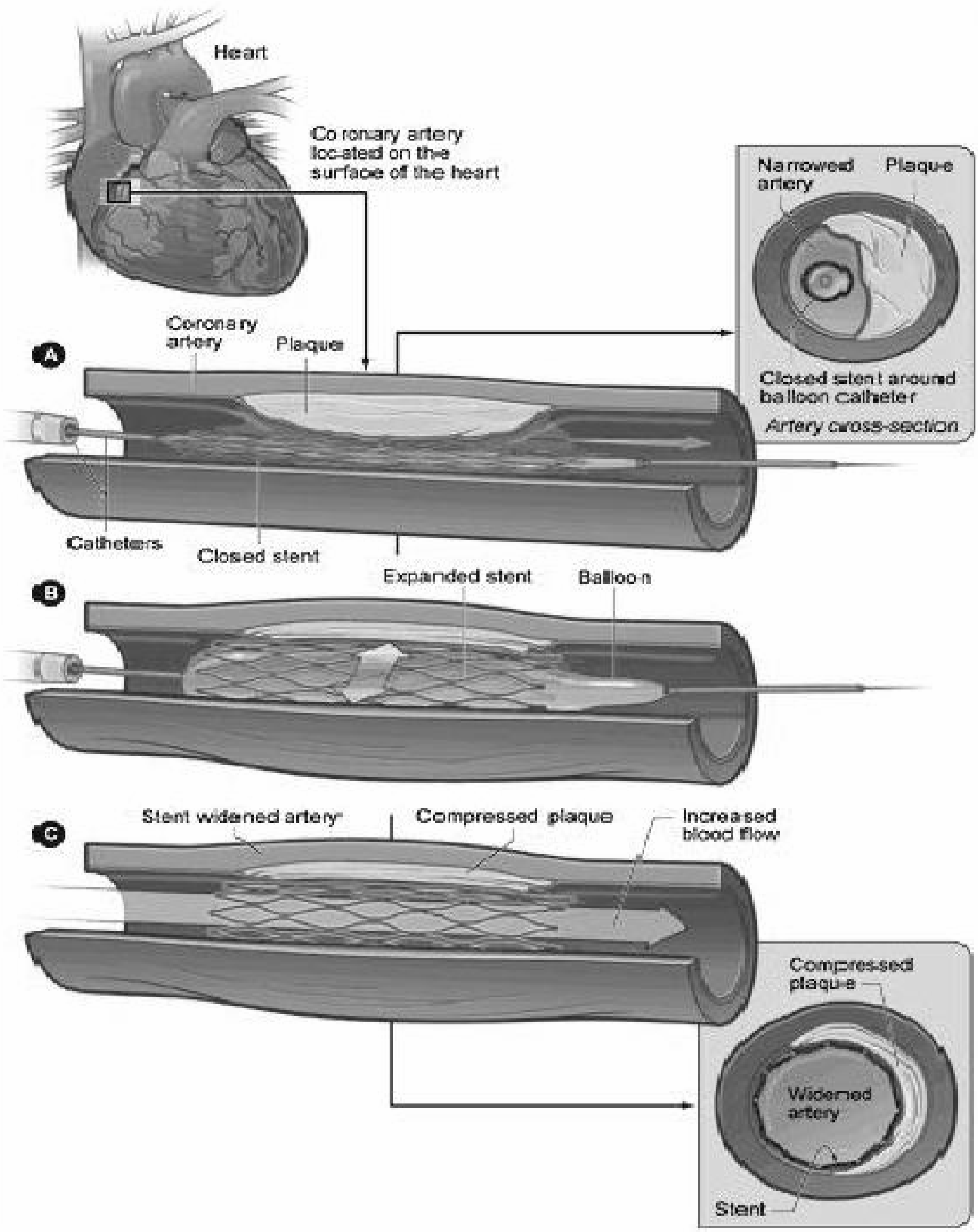

Figure 4. A coronary stent

2.1. Intraocular lenses

Cataract is a condition of loss of transparency of the lens of the eye or of its capsule, varying in degree from slight to complete opacity. This may result in gradual reduction of vision to complete obstruction of the passage of light and images to the retina.

The most effective and common treatment of a cataract is the surgical, i.e. removal of the lens and its replacement with a suitable artificial lens (an implant), which results in restoration of patient's vision and quality of life.

The surgical intervention consists of breaking and removing the cloudy natural lens with a miniature probe through a very small incision (of about 2-2.5mm).

After then, an artificial lens is implanted through the same incision and the visual function of the eye is restored. The intervention is bloodless and sutureless.

Usually, the cataract extraction takes 20 or some more minutes and the majority of patients return quickly and easily to their normal rhythm of life.

This is due to the artificial intraocular lens (IL) implanted into the eye during the final stage of the surgical intervention. The intraocular lens **(Figure 5)** is an artificial lens, which replaces the cloudy cataract and restores the visual function of the eye. The traditional method of cataract surgery includes the insertion of a monofocal lens, which corrects hyperopia and avoids the necessity of wearing glasses for myopia and correction of the existing astigmatism.

The new generation of artificial lenses aims at correcting some refraction anomalies, such as astigmatism, myopia and hyperopia. Besides, the improved design of the lens surface protects the eye (retina) from the ultraviolet spectrum of the daylight and improves vision in unfavourable light conditions (in foggy weather or at dusk).

Types of intraocular lenses:

- Intraocular implants with one focus and a filter for UV and blue light
- Intraocular implants with more than one focus
- Multifocal lenses, correcting hyperopia and myopia.

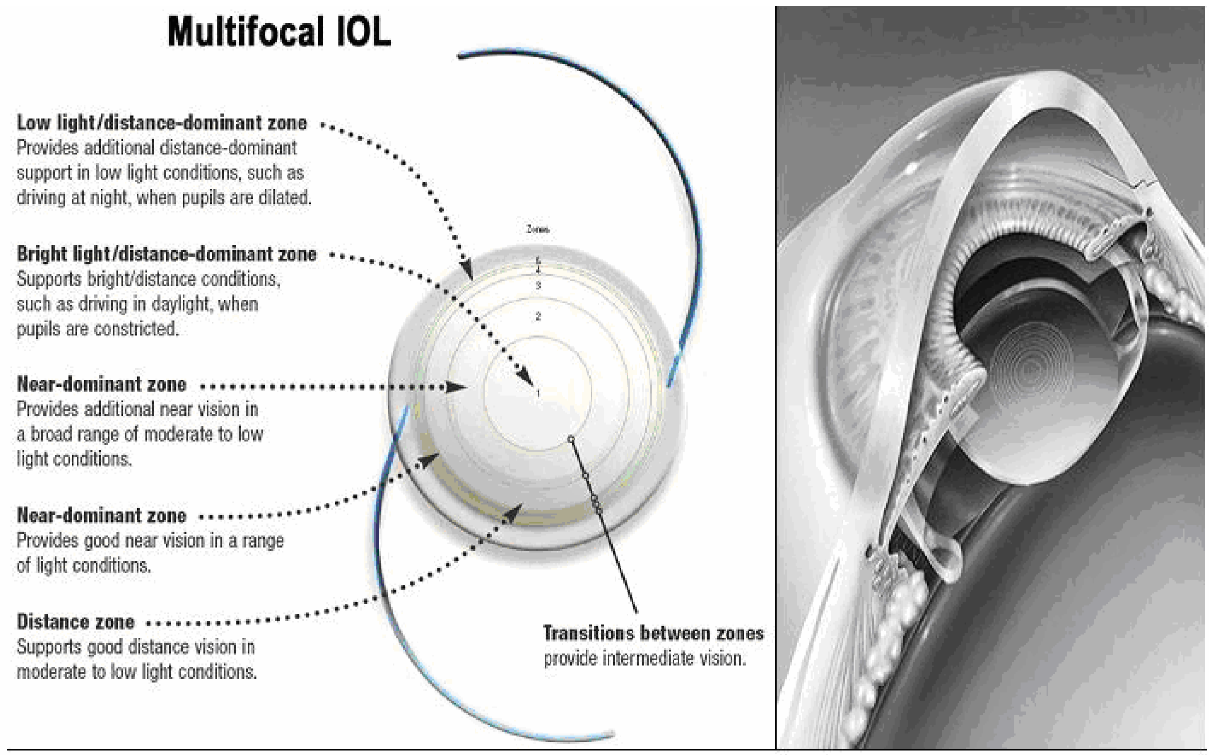

Figure 5. An intraocular lens

2.2. Artificial cornea

In March 2004, Dr. Ming Wang entered in the history of medicine as the first surgeon in the world who succeeded in implanting an

artificial cornea (alphacor). This revolutionary surgical intervention can help people who have lost their vision due to corneal damage and who have been irresponsive to other treatment methods.

Alphacor is an artificial cornea made of a biocompatible, flexible, hydrogel material, relative to the material used for soft contact lenses. It consists of a central transparent zone with refractive properties and a periphery, which stimulates the restoration of the eye onto the foreign body.

3. DENTAL IMPLANTS

Being an artificial substitute of the lost tooth, the dental implant is used in dental prosthetics as a support of bridges and crowns. There are several types of dental implants, generally classified as osseointegrated and fibrointegrated implants.

Presently, the most commonly used and successful implants are the osseointegrated titanium screw implants (Figure 6), which are based on the fundamental inventions of the Swedish Professor Per-Ingvar Brånemark, who put the basis of contemporary implantology 30 years ago. He has proved experimentally that the intraosseously implanted titanium is surrounded by a newly formed bone, adhering to it – a phenomenon, called "osseointegration". This is a remarkable, rarely observed in the nature process – namely, the creation of a bond between the living tissue (bone) and the foreign body (titanium/metal). Thus, the structural and functional relationships between the bone and implant are formed, making the bone-implant complex a complete unit.

Figure 6. Appearance of the most commonly used dental implants

After the rise of implantology, the variety of implants and implant systems is difficult to be described. Different criteria for implant classification are used. According to their shape, 98% of the modern implants are helical. According to the material of which they are made, titanium implants are mostly used, although there are some implants made of ceramics. In fact, the wide variety of implants is due to their most important part, the surface of the implant. For creating a maximum strong bone-implant bond and a large contact surface, the specialists test different types of implant surfaces and coatings. There are implants with various threads, specifically grooved apexes and various coatings – hydroxyapatite or triphosphorous complexes, acid- or laser-roughened surfaces.

REFERENCES

1. Dineen MK, Shore ND, Lumerman JH, Saslawsky MJ, Corica AP (2008). "Use of a Temporary Prostatic Stent After Transurethral Microwave Thermotherapy Reduced Voiding Symptoms and Bother Without Exacerbating Irritative Symptoms". J. Urol. 71 (5): 873–877.
2. Ali Riza Kural, İlter Tüfek, Haluk Akpinar, Adil Gürtuğ. Journal of Endourology. November 2001, 15(9): 947-948.
3. Kumar GVP; Mathew L. "Novel stent design for Percutaneous aortic valve replacement". 4th Kuala Lumpur International Conference on Biomedical

Engineering 25–28 June 2008. Springer Link. pp. 446–8.
4. PraveenKumar GVP; Mathew L. "Design for Percutaneous Aortic Valve Stent". International Conference on Biotechnology Proceedings, VIT University, Feb 8, 2008. pp. 139–40.
5. Kumar GVP; Mathew L. "New Stent Design for Percutaneous Aortic Valve Replacement". International Journal of Cardiovascular Revascularization Medicine **10** (2): 121–4.
6. Kumar GVP; Mathew L. "Effects of Stent Design Parameters on the Aortic Endothelium". 13th International Conference on Biomedical Engineering, Singapore, 3–6 December 2008. **23**. pp. 1539–42.
7. Rompen E, Dasilva D, Lundgren A.K, Gottlow J, Sennerby L : Stability measurements of a doubletreaded Titanium Implant design with turned or oxidized surface. An experimental Resonance frequency analys study in the dog mandibule Applied Osseointegration Reseach 2000;1 (1) : 18-20
8. Godfredsen K, Berglundh T, Lindhe J : Bone reactions adjacent to titanium implant with different surface Characteristic subjected to static load A study in the dog Clinical oral Implants Research 2001 : 12 : 196-201
9. Sykara S.N, Lacopino A.M, Marker V.A, Triplett R.G, Woody R.D Implant material, designs and surface topographies : Their effect on osseointegration Literature Review Oral Maxillofac Implants 2000; 15 (5) : 675-690
10. Kfron N. Contact Lens Complications 2nd edition. Oxford, UK: Butterworth-Heinemann, 2004.
11. Lighe B: Soft lens materials. In Kfron, ed. Contact Lens Practice. Oxford: Butterworth-Heinemann, 2002: 81.
12. Marilyn Haddrill. "Crystalens & Accommodating Intraocular Lenses for Cataract Surgery". All About Vision. Retrieved 2010-05-11.
13. Macsai et al. Visual outcomes after accommodating intraocular lens implantation. J Cataract Refract Surg. 2006 Apr; 32(4): 628-33
14. Cummings et al. "Clinical evaluation of the Crystalens AT-45 accommodating interocular lens Results of the U.S. Food and Drug Administration clinical trial. J Cataract Refract Surg. 2006 May; 32(5): 812-25.