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Immediate load implants. Thermal effects during abutment preparation

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Summary
Immediate load implants. Thermal effects during abutment preparation.

After insertion of immediate loaded implants, abutment preparation can be required to allow temporization. Thermal increase due to titanium cutting could cause heat damage and delay bone healing. Purpose of this study is to measure temperature variations along the implant body during preparation.
Materials and methods. **Implant abutments (Nobel Direct™, Nobel Biocare Ab, Goteborg, Sweden) have been reduced with tungsten carbide and diamond burs (Titanium Bur Kit, Nobel Biocare; U550 Maillefer), using different cooling systems (standard, additional, no cooling). Temperatures have been recorded at 30 and 60 sec via embedded thermocouples at the cervix, medium and apex of implant surface.**
Results. **Abutment reduction with quality burs, using intermittent cutting and adequate cooling system, is unlikely to cause an interface temperature increase sufficient to compromise bone healing.**

Key words: abutment preparation, immediate load, heat damage.

Sommario
Impianti one-piece a carico immediato: rialzo termico in fase di preparazione dell'abutment.

Dopo l'inserimento di impianti one-piece, realizzati esclusivamente per il carico immediato e caratterizzati da un abutment in titanio fuso con la vite piena della fixture, può essere necessario rettificare il moncone per consentire il posizionamento del restauro provvisorio. Il rialzo termico dovuto al fresaggio del titanio può causare danno termico a carico dell'osso e quindi ritardo nella guarigione. Scopo di questo lavoro è stato misurare *in vitro* le variazioni di temperatura lungo il corpo dell'impianto durante la preparazione.
Materiali e metodi. **I monconi degli impianti (Nobel Direct™, Nobel Biocare Ab, Goteborg, Svezia) sono stati preparati con frese multilame al carburo tungsteno e diamantate (Titanium Bur Kit, Nobel Biocare; U550 Maillefer) applicando diverse metodiche di raffreddamento (standard, addizionale, assenza di raffreddamento). La temperatura è stata rilevata con un termometro a termocoppia a 30 e 60 sec, a livello del terzo cervicale, medio e apicale.**
Risultati. **Una metodica di preparazione che preveda l'utilizzo di frese di qualità, una tecnica di taglio intermittente e un adeguato raffreddamento non determinano rialzi termici all'interfaccia tali da influenzare la riparazione ossea.**

Parole chiave: preparazione del moncone, carico immediato, danno termico.

Introduction

The use of osteointegrated implants introduced a new concept in dentistry: nowadays it is possible to replace missing teeth without neither loosing healthy dental tissue to project a fixed prosthesis nor resorting to the less acceptable solution of a mobile prosthesis.
First ten years of implants clinical experience brought Branemark to define some surgery and prosthodontics guidelines. Branemark principles state that a variable amount of time is needed before implant loading: he suggested to wait a healing period of 3-6 months, even not excluding the theorical possibility of an earlier loading in particular cases.

Immediate loading

Immediate loading concept was first introduced as a temporary solution. This way patients could have an acceptable fixed prosthesis during the long healing period. The first immediately loaded implants were in fact secondary ones, while waiting for bone healing around the submerged implants that had been inserted in primary sites. After Salama (1995) explained the principles for immediate implant loading, this became a valid and autonomous alternative to the traditional loading regime.
To understand clearly this concept it is important to define different commonly used terms, such as immediate loading, early loading, immediate function and others. The term "immediate functional loading" indicates that implant is loaded within 48 hours from insertion: it is

completely functionalized, i.e. it attends all the normal functions of oral system. "Non functional immediate loading" or "immediate function" refers only to aesthetic and speaking function of the provisional restoration, inserted on implant within 48 hours without occlusal contact. Other terms, as "early loading" or "previous loading", mean that implant is put in occlusion after 3 weeks and 8-10 weeks respectively: healing time in absence of load is however shorter than those indicated by Branemark (Gapski, 2003).

In conclusion, immediate loading is achieved by positioning immediately a provisional restoration on the inserted implants. This method provides a high quality treatement, focusing particularly on aesthetic, psychological and functional aspects.

On the other hand, many requirements must be satisfied in order to apply an immediate load with success. Immediate loading can be projected in patients without any systemic and local diseases. No inflammatory states or infections must be present. Patients with bruxism or functional disorders should be excluded.

Other prerequisites for success in an immediate loading treatment include: 1. infliction of minimal trauma during surgery; 2. establishment of high primary implant stability; 3. avoidance of any heat damage to bone (Glauser, 2001).

Bone healing

Installation of implants in the alveolar process elicits a sequence of healing events including necrosis and subsequent resorption of traumatized bone around the titanium body concomitant with new bone formation. Bone healing is a very complex process that involves the coordinated participation of immigration, differentiation and proliferation of inflammatory cells, angioblasts, fibroblasts, chondroblasts and osteoblasts, which synthesize and release bioactive substances of extracellular matrix components (e.g., different types of collagen and growth factors). Even having reference to this biologic sequence, many individual or local factors can affect bone healing. These factors (load, fracture type, gap width, blood flow, hormones and growth factors concentration,...) can influence bone physiology and modify healing dynamics (Doblarè, 2004)

We can differentiate between primary and secondary fracture healing. Primary healing occurs in cases of extreme stability and negligible gap size, involving a direct attempt by the bone to form itself directly. Secondary healing occurs when there is not enough stabilisation and gap size is moderate. In this case, healing activates responses within the periosteum and external soft tissues that form an external callus, which reduces the initial movement by increasing stiffness. It would be preferable to achieve a primary bone repair, which results in a higher quality bone formation in shorter time, particularly around immediately loaded implants. Avoiding tissue necrosis allows bone to heal by direct integration in 6 weeks, as a simple fracture. The prerequisites to obtain primary bone healing are: 1. reduction of bone exposition during surgery; 2. avoidance of compression on receiving bone; 3. reduction of thermal stress (Andreana, 2002).

Heat damage

Avoidance of heat damage, or thermal damage, appears to be a shared prerequisite to achieve both primary bone healing and success in immediate implant loading. This kind of damage occurs when bone temperature exceeds 47°C (protein denaturation threshold).The effect of overheating the bone at the interface may cause cell death, vascular stasis and tissue necrosis and compromise the bone's ability to survive as a differentiated tissue.

During surgical and prosthetic procedures in implant treatment, temperature can increase as a result of mechanical heating – i.e. when using cutting instruments for bone or titanium drilling – or chemical heating –- i.e. from exothermic setting reactions of autopolymerizing acrylic resins, used to adapt provisional restorations (Ormianer, 2000).

Many Authors (Benington, 2002; Eriksson, 1986; Eriksson, 1984) have investigated the thermal effects of surgical trauma, but potential thermal risk associated with titanium drilling is not well known. Of special concern is the need of an individual abutment preparation, that might interfere with bone and soft tissues healing as well. Indication for the need to prepare implant abutments include aesthetic aspects to place a crown margin slightly sub-mucosally, opening of an interproximal space if two implants (or an implant located next to a tooth) were placed too closely together, shaping the secondary part providing optimal space for framework and porcelain,and preparation of grooves for retention and resistance to rotational forces (Bragger, 1995; Gross, 1995).

Recently a new implant for immediate load (Nobel Direct™, Nobel Biocare) has been produced (Fig. 1). This is a one-piece implant with an integrated abutment that can be modified at the end of surgical phase to allow

Figure 1 - One-piece implant (Nobel Direct™, Nobel Biocare).

positioning of an immediate provisional restoration. Abutment preparation can be performed with different techniques, drills and cooling methods.
The aim of this study was, therefore, to assess *in vitro* the heat generated within the implant body when preparing Nobel Direct™ titanium implants to estimate the potential risk of tissue damage from individual abutment preparation.

Materials and methods

In vitro model design

The implants (Nobel Direct™, Nobel Biocare), 3,5 mm in diameter and 13 mm in length, were randomly selected from clinical storage. All the pieces have been inserted in plexiglas supports so that the abutment and 0,5 mm of the smooth implant neck were exposed. Implant bodies were then embedded in a transparent acrylic resin model (Leocril, Leone). After setting of the resin, three holes of 2 mm in diameter and 10 mm depth were drilled into the components and the tips of the thermo-elements were placed into the prepared cavities and held by friction fit.

Temperature recording system

Solid state temperature sensors K-type (Chromel-Alumel) were connected to a monitoring system (Hanna Instruments). The sensors used were capable of measuring temperature changes of 0,1°C, with precision of 0,5°C. Data were recorded at a rate of one sample per 0,55 sec.
The temperatures were measured at three different locations: coronal (T1), medium (T2) and apical (T3) portion of implant body (Fig. 2). An additional electrode was suspended in the air to measure the ambient room temperature.

Preparation of abutments

A high speed turbine hand piece (TitaniumGold, Castellini) with a rotation speed of 355.000 rpm was used at maximum free-running speed, with air pressure of 2,6-2,8 bars and water flow of 80 ml/mm with 1 bar pressure. The air-water coolant temperature was 22,4°C. In one group of cuttings, an additional air water spray from a syringe was added with a temperature of 20,1°C.
Three types of burs have been used to cut titanium abutments: a straight diamond bur and a straight tungsten carbide bur (Titanium Bur Kit, Nobel Biocare),both dedicated to titanium drilling, and a 50° preparation tungsten carbide bur (Tungsten Bur FG 550 of Prof. Barlattani, Maillefer).
All cuttings were performed by two operators (Op.), in horizontal and circumferential-vertical directions, to simulate intraoral procedure of abutment contouring. A continuous force was applied for 60 seconds, recording temperatures at 30 and 60 seconds.
Every bur has been used without cooling, with standard turbine air-water coolant and with additional coolant. The plexiglas support prevented the water-coolant spray from draining onto the sensors and changing the temperature (Fig. 3).

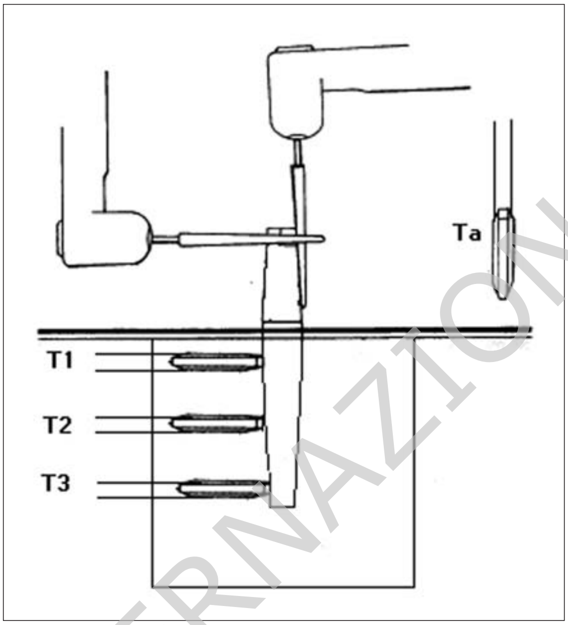

Figure 2 - Temperatures in the cervix (T1), medium (T2) and apex (T3) of implant surface were recorded.

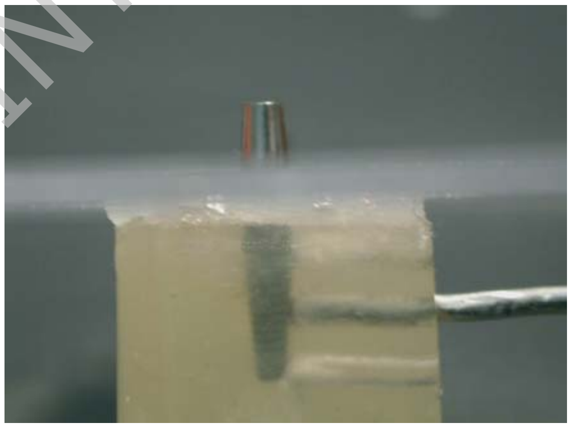

Figure 3 - Sample view. Looking down on: implant abutment, plexiglass support for the thermal insulation of the area from coolant; implant body embebbed in a transparent acrylic resin model, the holes for the probe insertion.

Results

Continuous cutting caused a gradual and constant temperature increase to a maximum at 60 seconds. Thus, time resulted the most influent variable of those considered (type of bur, cooling method, operator) (Fig. 4).
Cuttings performed with diamond burs caused greatest temperature increases. From a starting point of 21,8°C, a maximum of 30,9°C was recorded at coronal location without air-water cooling, with an increase of 9,1°C. With standard cooling, maximum increase of 1,9°C was measured at coronal and medium level; with additional coolant the main increase was of 1,4°C at medium location.

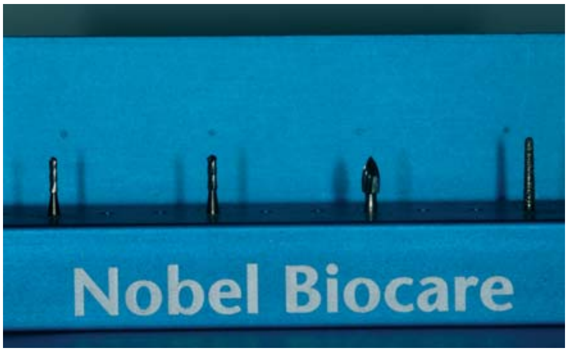

Figure 4 - Bur kit to cut titanium abutments (Titanium Bur Kit, Nobel Biocare).

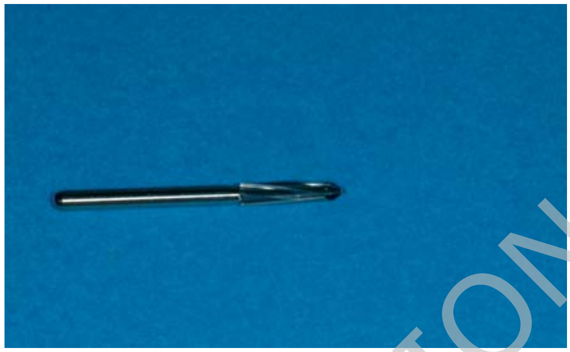

Figure 5 - 50° preparation tungsten carbide bur (U550 Maillefer del Prof. Barlattani).

Temperature increases ranged from:
– 4,6-9,4°C with no cooling;
– 0,4-1,9°C with standard cooling;
– 0,2-1,4°C with additional cooling.
Cuttings performed with tungsten burs (Fig. 5) showed comparable effects. Titanium dedicated bur caused a mean increase of 8,0°C at coronal level when cutting without cooling. When using a coolant, maximum increases of 1,7°C (standard) and of 1,1°C (additional) were recorded at medium level; 50°preparation bur (Fig. 6) provoked a maximum increase of 7,7°C without cooling, of 1,2°C with standard cooling and of 0,6°C with additional cooling (Tables I, II, III).

Figure 6 - The implant abutment and a 50° preparation bur.

Table I - Temperatures recorded in the cervix, medium and apex of implant surface.

Diamond bur (Titanium Bur Kit)								
Application time		T0	30”			60”		
No cooling	Op.1	21.8	27.4 (C)	28 (M)	27.3 (A)	30.6 (C)	29.8 (M)	29.7 (A)
	Op.2		28.1	27	26.4	30.9	29.9	28.8
Standard cooling	Op.1	20.9	21.6	21.8	21.3	22.7	21.9	22.4
	Op.2		21.7	21.8	21.7	22.8	22.8	22.4
Additional cooling	Op.1	20.4	20.7	20.9	20.6	21.1	20.9	21
	Op.2		20.9	21.1	21	21.4	21.8	20.9
Tungsten carbide bur (Titanium Bur Kit)								
Application time		T0	30”			60”		
No cooling	Op.1	21.8	25.4	23.8	23.4	29.8	27.6	25.2
	Op.2		25.8	24	23.1	28.9	26.4	26
Standard cooling	Op.1	21.7	22	22.2	21.9	23.4	22.9	22.8
	Op.2		21.9	22	21.9	22.9	22.7	22.4
Additional cooling	Op.1	20.9	21.6	21.3	21.2	21.6	22	20.9
	Op.2		20.8	20.4	20.7	21	21.2	21
Tungsten carbide bur (FG550 Maillefer of Prof. Barlattani)								
Application time		T0	30”			60”		
No cooling	Op.1	21.1	23.8	23.4	21.9	28.8	27.3	24.6
	Op.2		23.6	24.8	24	26.7	25.9	26
Standard cooling	Op.1	21.7	21.9	22	21.8	22.9	22.3	22.4
	Op.2		21.9	22.3	21.7	22.8	22.4	21.9
Additional cooling	Op.1	21.1	21.4	21.2	21.2	20.9	21	21.7
	Op.2		20.7	21.3	21.1	21	21.1	21.5

Table II - Fluctuations of temperatures recorded in the cervix, medium and apex of implant surface.

Diamond bur (Titanium Bur Kit)								
Application time		T0	30”			60”		
No cooling	Op.1	21.8	5.6 (C)	6.2 (M)	5.5 (A)	8.8 (C)	8 (M)	7.9 (A)
	Op.2		6.3	5.2	4.6	9.1	8.1	7
Standard cooling	Op.1	20.9	0.7	0.9	0.4	1.8	1	1.5
	Op.2		0.8	0.9	0.8	1.9	1.9	1.5
Additional cooling	Op.1	20.4	0.3	0.5	0.2	0.7	0.5	0.6
	Op.2		0.5	0.7	0.6	1	1.4	0.5
Tungsten carbide dur (Titanium Bur Kit)								
Application time		T0	30”			60”		
No cooling	Op.1	21.8	3.6	2	1.6	8	5.8	3.4
	Op.2		4	2.2	1.3	7.1	4.6	4.2
Standard cooling	Op.1	21.7	0.3	0.5	0.2	1.7	1.2	1.1
	Op.2		0.2	0.3	0.2	1.2	1	0.7
Additional cooling	Op.1	20.9	0.7	0.4	0.3	0.7	1.1	0
	Op.2		-0.1	-0.5	-0.2	0.1	0.3	0.1
Tungsten carbide bur (FG550 Maillefer del Prof. Barlattani)								
Application time		T0	30”			60”		
No cooling	Op.1	21.1	2.6	2.3	0.8	7.7	6.2	3.5
	Op.2		2.5	3.7	3.6	5.6	4.8	4.9
Standard cooling	Op.1	21.7	0.2	0.3	0.1	1.2	0.6	0.7
	Op.2		0.2	0.5	0	1.1	0.8	0.1
Additional cooling	Op.1	21.1	0.3	0.1	0.1	-0.2	-0.1	0.6
	Op.2		-0.4	0.2	0	-0.1	0	0.4

Table III - The peak fluctuations of temperatures recorded in the cervix (C), medium (M) or apex (A) of implant surface.

	Diamond bur (Titanium Bur Kit)		Tungsten carbide bur (Titanium Bur Kit)		Tungsten carbide bur (50° of Prof Barlattani)	
Application time	30”	60”	30”	60”	30”	60”
No cooling	6.3 (C)	**9.1 (C)**	4.0 (C)	8.0 (C)	3.7 (M)	7.7 (C)
Standard cooling	0.9 (M)	1.9 (C.M)	0.5 (M)	1.7 (C)	0.5 (M)	1.2 (C)
Additional cooling	0.7 (M)	1.4 (M)	0.7 (C)	1.1 (M)	**0.4 (C)**	0.6 (A)

Discussion

The findings of this *in vitro* study reveal some information about the considered variables:

Cooling system

First, we can notice that preparation cannot be performed safely without an adequate cooling system. The maximum temperature increases measured without cooling range from 7,7 to 9,1°C. A thermal increase of such entity could result in severe heat damage to bone, considering that “ideal temperature to avoid bone overheating is 39°C, because necrosis occurs when temperature rises over 43°C” (Pacifici, 1999).

Burs

Diamond bur seems to cause higher temperature increases than tungsten carbide ones, despite of time of application and cooling methods. This is probably due to its abrasion action and to its wider contact surface. This factor can enhance heat production because of attrition and also seems to reduce cooling efficiency. On the contrary, tungsten burs shape allows the presence of water between the blades, so that detritus can be removed dissipating excessive heat.
The two types of tungsten burs tested have shown similar results, though they were projected for different purposes: titanium drilling and natural tooth preparation.
Furthermore, 50° preparation bur has provoked the

lowest temperature increases (0,6°C versus 1,1°C with additional cooling, 1,2°C versus 1,7°C with standard cooling). This could mean that titanium abutment can be prepared as a natural teeth, applying the same techniques and instruments used in fixed prosthodontics.

Preparation technique

Continuous cutting caused temperature increases that ranged from 0,6 to 1,9°C, excluding the tests without cooling. Temperature increase is in fact proportional to application time. These results show that continuous cutting for 30 and 60 seconds should keep temperature in a safe range to avoid heat damage to bone.

Additional cooling

In contrast with other Authors results (Gross, 1995), these measurements indicate that additional cooling is effective in avoiding excessive temperature rising. Using additive coolant kept temperature increases between 0,6 and 1,7°C at 60 seconds, while at 30 second we recorded a temperature decrease at coronal level. In these cases cooling effect seems to prevail on heating, at least in an early phase.
It is interesting to observe that, while maximum changes have been often recorded at coronal level, they were measured at medium-apical level when using additional cooling. While titanium low thermal conductivity prevents from overheating along the implant body, this same thermal property seem to enhance the effectiveness of the coolant.

Conclusions

According to the literature reviewed and the results obtained in this study, we can conclude that an intraoral preparation, performed with quality burs, using an intermittent cutting technique and an adequate cooling system, appears to be the optimal procedure to induce minimal thermal changes at the bone implant interface. Additional cooling with air-water syringe can help keeping temperature lower than standard cooling alone.
Even if abutment cutting may not have deleterious thermal effects, it may affect bone healing through micromovements and vibrations. The effect of mechanical vibration on immediately loaded implants has yet to be studied.
This preparation technique helps reducing thermal risks, that could severely affect bone healing around immediately loaded implants. This way it is possible to treat a one-piece implant as a natural tooth to be restorated with a fixed crown, applying the same guidelines of fixed prosthodontics to teeth and implant retained restorations.

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