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EFFECT OF DIFFERENT TYPE AND TEMPERATURE OF IRRIGATION SYSTEMS ON CONTROLLING HEAT GENERATION DURING OSTEOTOMY- A REVIEW

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ABSTRACT

Statement of problem: Heat generation during osteotomy is unavoidable and use of irrigation is mandatory. Therefore, this review aims at addressing different types of irrigation systems, and effect of their temperature on controlling the heat generation during osteotomy. **Materials and Methods:** To identify suitable literature, an electronic search was performed using Medline and Pubmed database. Articles published in between 1960 to 2020 were searched. The search was focused on irrigation systems used during dental implant placement surgery. The initial literature search resulted in 226 articles out of which only 14 articles fulfilled the inclusion criteria and were included in this review. **Results: Conclusion:** Different irrigation systems are available and there seems to be no consensus on the most recommended method of irrigation. It can be concluded that the drill speed plays an important factor to decide the use of irrigation system for osteotomy. It is mandatory to use external irrigation when higher speeds are used with larger drills. Dual systems can be recommended when longer length osteotomy and enblock resection is performed. Implants placed with irrigation solution of 1°C has shown to have better osseointegration.

KEYWORDS: Dental implants osteotomy, irrigation system, temperature of irrigation solution, osseointegration, heat production, Implant drill speed.

INTRODUCTION

Dental implants have been serving as a standard treatment option for the replacement of missing teeth. It has been well established that the success and longevity of implants depend on the quality of osseointegration, which in turn depends on various parameters such as implant design, surface characteristics, bone density, surgical technique, timing of placement, and loading protocol.[1] Surgical technique involves drilling the bone to receive specific implant fixture and is referred to as osteotomy preparation. The preparation of implant site will cause mechanical damage to the site. During this process, heat generation adjacent to the implant site is unavoidable. Since bone is a liable tissue and is very sensitive to heat, efforts are made to control the temperature during osteotomy preparation. As reported by Erikson and Alberktson, the critical temperature of bone is in the range of 44- 47 °C and the threshold temperature for heat induced bone injury is 47 °C for 1 min.[1]

Drilling of the bone to receive an endosseous implant can produce a large amount of local inflammatory reaction which will further jeopardize the process of osseointegration by inhibiting bone microcirculation and activation of the bone marrow macrophages. An essential prerequisite given by Albrektsson et al. 1981 and revisited by Benington et al. 2002 states that for primary healing of dental implants is to preserve healthy bone by atraumatic surgical preparation of bone.[2] The overheating of the crestal bone due to countersink preparation in crestal region has been proposed to be a reason for the early marginal bone loss. Amount of heat generated can be affected by various factors such as drilling speed, drill feed, drill status, drilling depth, drill design, irrigation system, and drill sharpness.[3] In 1982, a study conducted by William R. Krause concluded that by the use of adequate irrigation technique, the temperature and risk of thermal necrosis can be controlled and/or reduced.[4] Further the experimental studies of Abouzgia & James 1997 emphasized the use of saline irrigation during osteotomies to prevent the increase in temperature of the bone.[5] It was noticed that

when continuous drilling was performed, there was a rise in temperature because of the decreased cutting efficiency of the drill due to clogging effect of the bone debris on the cutting edges. Therefore, adequate irrigation will eliminate the bone chips and can prevent the clogging effect that can further lower the friction produced during drilling and reduce the time required for surgical bed preparation.

There are three types of irrigation systems used in implantology; external, internal, and combination irrigation system. External irrigation system uses modified wide bore needle attached to handpiece for water delivery to bur for cleansing and cooling of the precise working area. It is proven that the efficiency of external irrigation system was reduced as the depth of preparation was increased. Therefore in Kirschner and Meyer (1975) proposed an interior liquid cooling method in surgical drills which directs cooling fluid to the point of contact between the drill's cutting surface and the bone. Internal system was introduced to be more efficient in providing debridement of the bone compared to external irrigation.[6] To prevent heat-induced bone tissue injuries many manufacturers' came up with a dual or combined irrigation system. This advanced system used external irrigation to reduce the superficial bone and internal irrigation to reduce the temperature in deeper region of osteotomy.[7]

Limited information is available in the literature on different irrigation systems and there seems to be no consensus on the most recommended type and temperature of irrigation systems. Therefore, we aimed to review the effects of various irrigation systems on the heat generation in the bone.

MATERIAL AND METHODS

Search strategy

A broad search of the dental literature in Medline and Pubmed was performed for articles published between 1960 through 2020. The key words searched were Dental implant osteotomy, Heat generation, Drill cooling, Implant drill design and Surface contact area. The search strategy included the combination of the following terms: "heat generated by implant drills, external and internal irrigation of dental implant drills, heat generated during osteotomy, effect of heat on osseointegration." Manual searches of the references of all full-text articles and relevant review articles selected from the electronic search were also performed.

Selection Criteria: A total of 226 articles were obtained when key terms were applied out of which 14 articles were selected and reviewed. Five of these studies evaluated change in temperature during osteotomy preparation with and without irrigation. Eight studies evaluated efficiency of various type of irrigation systems and three evaluated effect of irrigation solution temperature on heat generation.

Table 1: A synopsis of various studies on heat generation during osteotomy is given in.

Author	Purpose of study	Site of implant placement	Type of System	Type of temperature assessment	Study conclusion
Haider et al[8]	Internal versus external drill cooling on bone healing.	Sheep tibia	IMZ implant system	Healing in compact or spongy bone bed and foreign body reaction.	Particularly in compact bone, external cooling is advantageous with internal cooling
Benington et al[9]1996	Heat generated during the sequence of drilling for implant site preparation.	Bovine mandible.	A conventional dental handpiece was used with a motor provided by Nobel pharma (Harrow, UK).	infra-red thermographic imaging	There was considerable increase in the temperature when irrigation was not used and non-invasive method infra-red thermography can be used study temperature changes.
Benington et al[10] 2001	Compare the temperatures that were generated with external and internal irrigation systems.	Bovine mandible.	Osteotite capillary drills (3I,Palm Beach, FL, USA)	infra-red thermographic imaging	There appeared to be no significant increase in drill temperature with the use of external irrigation. There appears to be no clinical advantage in using internal systems over the more traditional and less expensive external flood irrigation method.
Sener et al[11] (2008)	Temperature of the saline solution and heat control.	bovine mandibles	Camlogs drill system	Thermal changes during drilling	1.More heat is generated in the superficial part of a cavity,

				without irrigation at various drilling depths Thermal changes during drilling with external irrigation of different temperature.	owing to the effects of the compact and spongious components of bone 2. Irrigation with saline at both 10 and 25C had a cumulative cooling effect.
Augustin et al 2008[12]	Evaluate different drill parameter and effect on heat production.	Cortical femoral specimens		Different Drill diameters- 2.5, 3.2 and 4.5 mm; drill speed 188, 462, 1,140 and 1,820 rpm; feed-rate 24, 56, 84 and 196 mm/min; drill point angle 80°, 100° and 120° and external irrigation with water of 26°C.	Combinations of drill speed and drill diameter with the use of external irrigation produced temperatures far below critical. Temperatures above critical were recorded using 4.5 mm drill with higher drill speeds (1,140 and 1,820 rpm). The external irrigation is the most important cooling factor.
KIM SJ et al[13]	Temperature change during low speed drilling using infrared thermography.	Pig ribs	Brånemark drill system (Nobelbiocare, Sweden) and Osstem drill system (Osstem, Seoul, Korea)		Low-speed drilling without irrigation did not increase bone temperature.
GIRO ET AL [14]	Thus, the objective of this study was to evaluate the influence of drilling technique on the early integration of 2 different surfaces of plateau root form implants.	Eight male beagle dogs			The authors concluded that both techniques showed similar results and did not affect the integration of implants
Georg D. Strbac (2012)[15]	Evaluate temperature changes with common external and internal saline irrigation methods under standardized conditions as compared to the effects of a combined external and internal irrigation system during implant site preparation.	bovine rib specimens	Special computer-aided customized surgical system (SH-Surgical Drilling-Sequence-Simulator System; Center for Medical Physics and Biomedical Engineering, Medical University of Vienna, Vienna, Austria). NobelReplace TM Tapered Drills, Nobel Biocare; Gothenburg, Sweden)		Internal irrigation appears to be superior to a combined irrigation method during an intermittent graduated drilling osteotomy. In contrast, the use of combined irrigation primarily seems to be superior to an external irrigation method at greater osteotomy depths
Gehrke et a.[16] 2013	External irrigation technique with those of a double irrigation technique with continuous and intermittent movement.	bovine rib invitro	Control group 1 (CG1) = external irrigation and continuous movement; control group 2		The double irrigation technique produced smaller increases in the temperature of bone compared with the external irrigation technique, regardless of the drilling

			(CG2) = external irrigation and intermittent movement; test group 1 (TG1) = double irrigation and continuous movement; and test group 2 (TG2) =double irrigation and intermittent movement.		movement, which suggested that double irrigation was more efficient
Gaspar J[17]	The purpose of this study is to evaluate immediate histological alterations in rabbit tibias, produced by low speed drilling (50 rpm) without irrigation and conventional drilling (800 rpm) under profuse irrigation.	Animal study on tibias of 6 White female rabbits	IDI implant drill system (IDI®, France) An electric motor (W.H. Implantmed®)		Based on our results, we can conclude that the effects of implant site preparation on bone by low speed drilling (50 rpm) without irrigation and conventional drilling (800 rpm) under profuse irrigation are similar. Both surgical drilling techniques preserve bone-cell viability and the clinician can decide which drilling technique to use, based on other criteria.
Gehrke et al.[18] 2014	compare temperature variation during osteotomies with trephine drills under different irrigation conditions: without irrigation, external irrigation, and double irrigation.	bovine rib invitro	Three groups were Formed depending on the irrigation conditions:no irrigation(G1), external irrigation (G2), and double irrigation (G3).		The double irrigation technique resulted in a smaller increase in temperature in the cortical bone model, demonstrating a greater efficiency, which may be beneficial when compared to external irrigation alone.
Gehrke et al[19] (2016)	influence of drill length and irrigation system on heat production during osteotomy preparation for dental implants using bovine bone rib as experimental model.	ex vivo study was performed on 48 adult bovine rib bone	NobelReplace implant, Nobel Biocare Straumann		The present study showed that all systems tested generate a moderate temperature variation during the osteotomy to preparing the implant site with to continuous drilling protocol even if varying the length. Moreover, the use a double irrigation system in multiple conventional drill sequence for osteotomy can decrease the internal thermal heat when increase the drill length.
Yılmaz D, etal.2020[20]	effect of different irrigation temperatures during implant surgery on the osseointegration of dental implants.	white rabbits (Oryctolagus cunilicus, New Zealand	(Anyone, MegaGen Implant		different irrigation solution tempatures during implant surgery did not have a direct effect on the primary and secondary stability values of dental implants
Gehrke[21] 2020	evaluated a new drill design to improve the temperature control during the osteotomies for dental implant installation,	synthetic cortical bone	(turbo drill) conventional external irrigation system single and multiple		The single drill with a new design for improving the irrigation and temperature control, in comparison with the drill designs with

	comparing with two drill designs that use conventional external irrigation.				conventional external irrigation.

DISCUSSION

With Irrigation Vs Without Irrigation

Kim SJ et al. concluded that drilling at 50 rpm without irrigation did not significantly increase the bone temperature. In addition, Giro et al. evaluated the effect of the surgical technique on implant integration, and concluded that osteotomies performed at 50 rpm without irrigation and 900 rpm with irrigation had similar effect on integration of implants.[14] According to Gaspar J et al., the effect on preservation of bone-cell viability at low-speed (50 rpm) drilling without irrigation and conventional drilling (800 rpm) under profuse irrigation were similar.[15] They suggested that clinician can decide which drilling technique to use, based on other criteria.

The advantages of low-speed drilling is as follows;

1. Easy control on path of drilling - high speed can change its drilling path on its own when it encounters a dense cortical bone. In Low-speed drilling, the operator can correct the path if it has been altered.
2. The potential risk of damaging the vital structures such as inferior alveolar nerve or maxillary sinus is minimal.
3. Gradual drilling causes less friction, and thus less trauma to the bone.
4. Bone collected during low-speed drilling may be easier to manipulate than bone collected by other methods, such as bone trap and bone collector. This is particularly important when clinically autogenous bone graft is needed with less contamination with saliva.
5. Low speed drilling prevents washing away and dissolving of osteoinductive signaling proteins and other biomolecules present in bone extracellular matrix, which have an important role in bone remodeling.

The disadvantage of low-speed drilling is it requires longer duration of drilling time when compared with high speed drilling. However, Benington et al have reported that temperature rises upto 130.1°C without irrigation when using a rotational speed of 2500 rpm.[9] Providing more insights, Augustin et al. found that the temperature range without external irrigation was high with all the drill speeds but it was above critical bone temperature with higher drill speeds (1,140 and 1,820 rpm). Therefore, the drill speed plays an important factor to decide the use of irrigation system for osteotomy.

External Versus Internal Irrigation

Benington et al. studied external and internal cooling systems of irrigation and indicated that both systems reduced the bone temperature to satisfactory levels.[9] Further in 2001, a similar study was conducted with the use of a constant load for standardization and concluded that there was no clinical advantage in terms of thermal changes in the bone with internal system. The added disadvantages of internal system would be its increased cost.[10]

Georg D. Strbac studied the effect of each system of irrigation on various types of bones and various depths of drilling.[15] The study concluded that an external irrigation method primarily reduces temperature only in the superficial cortical bone areas and suggested that in deeper site osteotomies, a combined irrigation system may be more beneficial. Thus use of combined system is advantageous in template-guided implant bed preparations or when longer burs used.

Gehrke et al. in 2013 showed that there was 12% low increase in temperature with double irrigation system when compared with only external irrigation system, regardless of the drilling movement.[16] Further same authors in year 2014 in their study with trephine drills concluded that dual irrigation is more efficient when compared with external irrigation. The use of a double irrigation system in multiple conventional drill sequence for osteotomy can decrease the internal thermal heat when increasing the drill length.[19] In 2020, the new single bur (turbo drill) was designed to provide with both external and internal irrigation and showed better temperature control.[21] In this direction, Robert Haider used a new IMZ implant system with internal cooling device. The cannon drill was used in this system which prevented the coolant outlet from becoming blocked with debris and bone chips.[8] The authors have recommended additional external cooling system could improve the efficiency.

Effect Of Temperature Of Irrigant On Heat Control

Saline at 5 °C was used to cool the drills and control heat generation in the bone. [2] Study conducted by Sener et al concluded that while sufficient cooling was achieved at superficial bone with irrigant at room temperature, cooling the saline at 10 ℃ and 25 ℃ was more effective in reducing the heat generation in deeper areas of the bone. This cooling of irrigation solution also provided anti-inflammatory effect at the operation site. Yılmaz D et al studied the primary and secondary stability after implant placement with different irrigation solution temperatures of 37℃, 24°C, 10°C, and 1°C during implant surgery. The authors concluded that there was no effect of irrigation solution temperature on osseointegration and ISQ values. But the secondary stability values were higher for implants placed with 1 °C irrigation solution temperature than 10 °C and 37 °C.

CONCLUSION

Adequate irrigation of the implant site is necessary to reduce the risk of bone necrosis during osteotomy preparation. Since modern implant systems use high speed drills for preparation of osteotomy site, it is mandatory to use external irrigation system. As the depth of preparation increases, it is recommended to use dual systems for irrigation. For better osseointegration irrigation solution temperature at 1°C can be used.

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