Assessment of the Heat Generation at the Marginal Bone Area during the Implant Insertion Using Infrared Thermography (Experimental study)

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Abstract: ***The aim of this study was to investigate the influence of the parameters of the implant micro- and macro design on the heat generation at the marginal bone area during the implant insertion using thermal camera. 200 test specimens of implants of different designs and dimensions were inserted into 200 artificial bone blocks and 200 test specimens were placed into 40 fresh pig ribs. It was established that the implant length influenced the heat generation more than the implant diameter and that the tapered design causes less temperature increase compared to the cylindrical design. We concluded that the heat generation during the implant insertion could be decreased be using shorter implants with smaller diameter and conical shape.***

Keywords: infrared thermography, implant insertion

1. Introduction

The bone overheating during the implant surgery could be the reason for the early implant failure. The aim of this study was to investigate the influence of the parameters of the implant micro- and macro design on the heat generation at the marginal bone area during the implant insertion.

2. Literature Survey

The heat generation during the implant site preparation is commonly measured using thermocouples or infrared thermal camera [1], [2], [3], [4], [5], [6]. The infrared thermography is a method, in which the radiation of infrared values is detected using thermograph, which also differentiates the distribution of the temperature as a visible image [7], [8].

Scarano et al. [9] used infrared thermography to assess the differences in the heat generation during the implant site preparation, using straight and conical drills. Möhlhenrich et al. [10] and others [11], [12] also used infrared camera to measure the increase of the temperature during the osteotomy for the implant placement.

Many authors have observed the heat generation during implant site preparation, but there is a less data reported about the temperature increase during the implant insertion [13]. The friction during the implant placement into a drill-prepared osteotomy can cause temperature rise [14]. Flanagan [14] and Marković et al. [15] measured the heat generation during the implant insertion using thermocouples. There is no data about the assessment of the temperature increase during the implant placement using infrared thermography.

3. Material and Methods

200 test specimens of implants of different designs and dimensions were inserted into 200 artificial bone blocks and 200 test specimens were placed into 40 fresh pig ribs. This study included four implant designs: cylindrical implants with 0.8 thread pitch - (C) implants , cylindrical implants with 1.2 thread pitch and deeper thread depth - (CD) implants, implants with tapered shape in their apical region – (TA) implants and implants which are tapered in their coronal region and cylindrical in their apical region – (TC) implants . The implants in each group (block-group and rib-group) were distributed as follows: 20 C implants with dimension 3.3 mm/10mm (3.3/10), 20 CD 3.3/10 implants, 20 TA 3.3/10 implants, 20 C implants with dimensions 4.1 mm/10mm (4.1/10), 20 CD 4.1/10 implants, 20 TA 4.1/10 implants, 20 TC 4.1/10 implants, 20 C implants with dimensions 4.1 mm/12 mm (C 4.1/12), 20 TC implants with dimension 4.8 mm/ 10 mm (4.8/10) and 20 CD implants with dimension 4.8 mm/8 mm (4.8/8).

In each group 10 of 20 implants are with smooth surface, colored by anodization and 10 are with rough surface, modified by sandblasting with large grit Al_2O_3 followed by acid-etching.

The site preparation protocol was the following:
1) The position of the osteotomy was marked with a 1.4 mm round bur
2) The mark was expanded with a 2.3 mm round bur
3) Pilot osteotomy was performed using 2.2 mm pilot drill to the appropriate depth at a maximum speed of 800 rpm
4) The osteotomy was enlarged consequently to the desired diameter with a 2.8 mm drill, then with a 3.5 mm drill and with 4.2 mm drill, as for the 3.3 diameter implants site preparation the final drill used was the 2.8 mm drill, for the 4.1 diameter implants – 4.2 mm drill and the last drill used for the site preparation of the 4.8 diameter implants was the 4.2 mm drill.
5) The orifice of the osteotomy was enlarged with a profile drill of a corresponding diameter.

The drills we used for the site preparation of the C, CD and TC implants were twisted and cylindrical and the drills we used for the AT implants osteotomy were conical with vertical grooves. The osteotomy was performed with continuous cooling with sterile saline solution. Before the insertion was performed, the artificial bone blocks and the pig ribs were stable fixed using vise. The implants were placed using contra angle handpiece CA 20:1 L Micro-series. The torque function of the implant unit iChiropro (Bien Air Dental SA, Bienne, Switzerland) controls and measures the insertion torque during the implant placement. Implants were inserted into the osteotomy with speed of 15 rpm.

During the implant insertion thermal camera FLIR (Flir Systems, Wilsonville, Oregon, United States) was used to measure the increase of the temperature at the marginal bone area. The assessment of the heat generation was done by shooting series of thermal images during the implant placement, as the first of them was shot at the beginning of the insertion and the last one – at its end. The camera was held 10 cm away from the artificial blocks and the pig ribs. The analysis of the thermal images was done using the thermal camera software – FLIR Tools. We put marks at the marginal bone area at the orifice of the osteotomy on each thermal image and then the software calculate the temperature at those points, as it can detect temperature differences as small as 0.1 °C. To obtain results about the temperature increase and about the influence of the implant diameter, length, surface topography and design on the heat generation we calculated the temperature differences between the value (C°) measured on the last image and the value measured on the first image (at the beginning of the insertion). On fig. 1 and fig. 2 are shown thermal images at the beginning and at the end of the implant insertion into artificial bone block.
The statistical analysis of the results was performed using IBM SPSS Statistics 19 software.

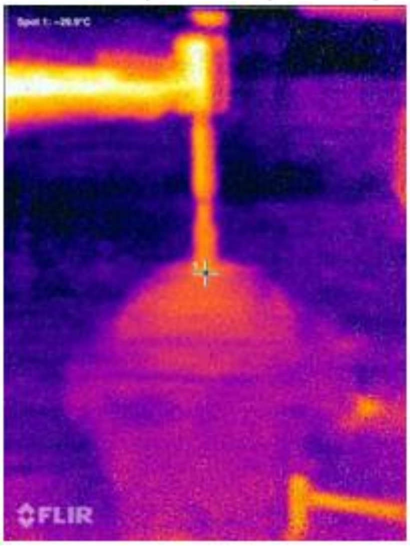

Figure 1: Thermal image at the beginning of the insertion (29.9^{0}C)

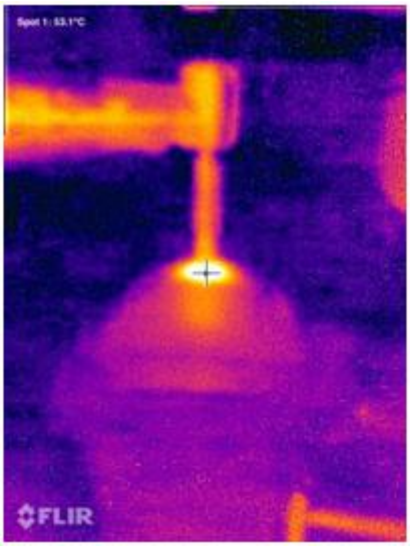

Figure 2: Thermal image at the end of the insertion (53.1^{0}C)

4. Results

The mean values of the temperature differences (TD) observed in artificial bone blocks and in the pig ribs, distributed by type or dimensions of the inserted implant group are shown at table 1.

Table 1: The mean values of the temperature differences, distributed by implant groups

A:type/dimensions Smooth surface	*Mean TD (°C) block*	*Mean TD (°C) rib*	*B:type/dimensions Rough surface*	*Mean TD (°C) block*	*Mean TD (°C) rib*
C 3.3/10	12.47	7.42	C 3.3/10	14.75	7.65
AT 3.3/10	7.98	5.46	AT 3.3/10	9.68	6.08
CD 3.3/10	11.28	7.11	CD 3.3/10	12.72	7.55
C 4.1/10	20.46	9.96	C 4.1/10	21.88	10.65
AT 4.1/10	12.31	6.87	AT 4.1/10	14.97	7.9
CD 4.1/10	17.26	8.98	CD 4.1/10	18.93	9.77
TC 4.1/10	13.87	7.85	TC 4.1/10	15.66	8.87
C 4.1/12	21.75	11.8	C 4.1/12	24.15	12.63
TC 4.8/10	16.22	8.91	TC 4.8/10	19.93	9.82
CD 4.8/8	14.17	7.96	CD 4.8/8	16.02	8.55

For each one of the 20 groups we observed lower mean values when inserting in pig ribs compared to the mean values observed during the insertion in artificial bone blocks.

To find out how does the implant diameter influence the heat generation at the marginal bone area we compared the difference between the temperature in the beginning and the temperature observed in the end of the implant insertion of an implants with different diameters, same length, same design and same surface topography.

When we compared the temperature increase during the insertion of 3.3 mm/10 mm and of 4.1 mm/10 mm (C) implants we observed the following relation: the insertion of larger diameter implants leads to higher heat generation at the marginal bone area. This relation applies also to the other 3 designs, when comparing the temperature rise during the insertion of smaller and larger diameter implants.

To investigate the effect of the implant length on the heat generation we compared the difference between the temperature in the beginning and the temperature observed in the end of the insertion of implants with different diameters, same length, same design and same surface modification.

We used the results obtained during the insertion of 4.1 mm/10 mm and 4.1 mm/12 mm cylindrical implants. We found the following relation: longer implants induce higher temperature increase at the marginal bone area during their placement compared to the shorter ones.

To establish how does the implant design affect the increase of the temperature at the marginal bone we compared the mean values, obtained during the insertion of implants with same dimensions (4.1 mm/10mm) and four different designs (C implants, CD implants, TA and TC implants). The highest heat generation was observed during the placement of the cylindrical implants with thread pitch of 0.8 mm, and the lowest values were assessed during the insertion of the apically tapered implants. The placement of cylindrical implants with thread pitch of 1.2 mm caused the second highest temperature increase and the insertion of marginally tapered implants leads to higher heat generation than the insertion of implants with apical conicity, but lower than the placement of the cylindrical implants with the wider thread pitch.

When we compared the heat generation during the insertion of an implants with dimensions 3.3 mm/10 mm and three different designs (C, CD and AT) we established the same relation: highest mean values of the temperature increase were demonstrated during the insertion of 0.8 mm thread pitch cylindrical implants and lowest – during the insertion of the implants with the conical shape in their apical region.

We also established relation between the surface topography and the temperature increase, as it was the same for all implant groups: the placement of implants with rougher surface leads to higher heat generation than the insertion of smoother implants.

Comparing all implant groups included in this investigation, the highest temperature rise was observed during the placement of 4.1 mm/ 12 mm cylindrical implants with the “narrower” thread pitch.

Compared to the other 9 groups implants, the insertion of the apically tapered implants with dimensions 3.3 mm/10mm leads to the lowest heat generation at the marginal bone area.

5. Discussion

The lower mean temperature values observed during the implant insertion in the pig ribs can be attributed to the water content in the fresh bone. The cylindrical implants demonstrated higher heat generation during their placement than the conical implants. The 1.2 thread pitch of the deeper thread profile cylindrical implants could be the reason for the lower temperature increase during their placement, compared to the cylindrical implants with 0.8 mm thread pitch. The insertion of apically tapered implants induced lower heat generation in the marginal bone area than the insertion of the implants, which are cylindrical shaped in their apical region and conical shaped in their coronal region. We observed the following relation: the implant length and the implant design influence the temperature increase more than the implant diameter.

Marković et al. [15] reported that the higher insertion torque is related to higher heat generation. That doesn’t match some of our results. During our investigation implants, which are tapered in their coronal third demonstrated highest maximum insertion torque values and lower maximum insertion torque values were observed during the placement of the cylindrical 0.8 mm thread pitch implants and the apically tapered implants, but we established highest temperature increase during the insertion of C implants and lowest – during the insertion of TA implants. Probably the reason is that the higher maximum insertion torque values of TC implants could be attributed to the larger diameter in their coronal region, but that conicity leads to a shorter-time insertion, which causes less heat generation. That’s the reason why the TA implants demonstrated the lowest temperature change during their insertion.

Flanagan [14] claimed that the implants with smaller diameter cause higher temperature rise during their placement, which is contrary to our results.

6. Conclusion

Within the limitations of this study we concluded that the heat generation during the implant placement could be decreased by using implants with tapered design. Insertion of shorter and smaller diameter implants could also prevent the bone from overheating. More data is needed about the temperature increase during the implant insertion in different types of bone.

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