Can ionizing radiation alter biomechanical and morphological bone tissue around the dental implant?

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Abstract

Background: The presence of metal in irradiation field can create a radiomorbidity of local tissue induced by increasing dose of irradiation, generated from backscatter high energy photons and electrons at the tissue-metal interface, which can compromise bone repair. Ionizing radiation (IR) can also be negatively influenced bone/implant integration resistance and little comprehensive information is available regarding the effects of scattered irradiation on regions with implants.

Aim: This study analyzed the effect of ionizing IR on bone microarchitecture and biomechanical properties in osseointegrated dental implants.

Materials and Methods: Twenty rabbits received 3 implants and were divided into 2 groups (n = 10): Control group (NoIr) - animals without IR; Irradiation group (Ir) - animals were irradiated with 30 Gy in a single dose, 2 weeks after implant installation. The animals were euthanized 4 weeks after implant installation, implant/bone were removed and submitted to microcomputed tomography (micro-CT) to calculate bone cortical volume (CtV), cortical thickness (CtTh) and porosity (CtPo). Elasticity modulus (E) and Vickers hardness (VHN) were calculated by dynamic indentation test. Failure load, displacement and stiffness were calculated from Pull-out test. Ir group were performed two measurements in micro-CT and dynamic indentation analyses: close 1 mm to the implant surface (Ir-C), and 2.5 mm from the external limit of the first close measurement (Ir-D).

Results: The bone of Ir-C group had lower E, VHN, CtTh, and CtV values and higher CtPo than the Ir-D group. Ir-D group had lower E, VHN, CtTh values and higher CtPo than the NoIr group. NoIr group had higher failure load, displacement and stiffness values than the Ir group.

Conclusions: IR in osseointegrated implants resulted in negative effects on microarchitecture and biomechanical properties of bone tissue, mainly near the surface of the implant.

Clinical Implications: The increase dental implant on rehabilitation and need for some patients submitted to radiotherapy, our results showed that IR decrease bone-to-implant contact in osseointegrated implants.

Methods and Materials

1. Surgical procedure

Morse taper implants - 3.5x7 mm (Neodent®)

2. Radiation protocol

- ✓ Single dose of 30 Gy was delivered
- ✓ 5-mm bolus was applied to ensure full build-up

3. Sample preparations

- ✓ After 4 weeks of the implantation, the animals were sacrificed

4. MicroCT analysis – Morphologic parameters

- ✓ The implant was circumferentially expanded, creating a 0.55mm zone around the implant.
- ✓ The volume of interest for cortical analyses was selected around the implant and defined as a column from implant axis with a radius of 1.5 mm within cortical bone (IrcIm).
- ✓ For comparing the effect of metal effect on radiation enhancement the same bone volume affected by radiation were measure 2.5mm (IrdIm) far from the external limit of the first measurement.
- ✓ The following microarchitecture was assessed in VOI images: **cortical volume (CtV), cortical thickness (CtTh) and porosity (CtPo)**

5. Dynamic Indentation Test

- ✓ Calculate mechanical properties - Elastic modulus and Vickers hardness
- ✓ Maximum force - 200 mN load
- ✓ 5 continuous indentations

6. Pull-out Test

- ✓ Calculate mechanical properties - failure load (N), displacement (mm) and stiffness (N/mm)

Results

Mean and standard deviation values Cortical volume CtV in mm³, cortical thickness CtTh in mm, and porosity CtPo in % measured by microCT analysis for non-irradiated and irradiated groups.

Groups	CtV (mm ³)	CtTh (mm)	CtPo (%)
NoIr, non-irradiated implants	6.9 ± 0.3 ^A	0.30 ± 0.06 ^A	65.9 ± 1.4 ^A
Ir, Irradiated implants	<i>Ir-C, measured close to the implant surface</i>	6.1 ± 0.3 ^C	0.33 ± 0.03 ^A
	<i>Ir-D, measured distant to the implant surface</i>	6.5 ± 0.3 ^B	0.31 ± 0.03 ^A

Letters represent significant difference within each morphological parameters, defined by Tukey test ($P < 0.05$).

Mean and standard deviation values of elastic modulus in GPa and Vickers hardness in N/mm² measured by dynamic indentation test for non-irradiated group and irradiated group measured close and distant from the implant surface.

Groups	Mechanical properties			
	Elastic modulus (GPa)	Vickers hardness (N/mm ²)		
NoIr, non-irradiated implants	20.8 ± 3.2 ^A	115.9 ± 32.5 ^A		
Ir, Irradiated implants	<i>Ir-D, measured distant to the implant surface</i>	18.3 ± 2.5 ^B	91.5 ± 32.0 ^B	
	<i>Ir-C, measured close to the implant surface</i>	16.1 ± 2.5 ^C	69.7 ± 27.2 ^C	

Letters represent significant difference within each mechanical property, defined by t-Student test ($P < 0.05$).

Mean and standard deviation values of failure load in N, displacement (mm) and stiffness in N/mm² measured by pull out test for non-irradiated group and irradiated group.

Letters represent significant difference, defined by t-Student test ($P < 0.05$).

Conclusion

Considering the limitations of this study, such as the fact that there is no load on the implants, and that were installed only in the cortical bone, we can concluded that radiotherapy in previously rehabilitated regions decreased the secondary dental implant stability measured by pull-out bond test, and also is able to alter the mechanical and morphologic properties of bone around implants which that can compromise the long-term prognosis.

References

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Background and Aim

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20 New Zealand white rabbits

✓ NoIr – no irradiated group

Ethics Committee for Animal Research

(Protocol #093/12, Universidade Federal de Uberlândia, Brazil)

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