Effect of light-curing, pressure, oxygen inhibition, and heat on shear bond strength between bis-acryl provisional restoration and bis-acryl repair materials

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PURPOSE. This study aimed to discover a way to increase the bond strength between bis-acryl resins, using a comparison of the shear bond strengths attained from bis-acryl resins treated with light curing, pressure, oxygen inhibition, and heat. **MATERIALS AND METHODS.** Self-cured bis-acryl resin was used as both a base material and as a repair material. Seventy specimens were distributed into seven groups according to treatment methods: pressure - stored in a pressure cooker at 0.2 Mpa; oxygen inhibition- applied an oxygen inhibitor around the repaired material,; heat treatment - performed heat treatment in a dry oven at 60ºC, 100ºC, or 140ºC. The shear bond strength was measured with a universal testing machine, and the shear bond strength (MPa) was calculated from the peak load of failure. A comparison of the bond strength between the repaired specimens was conducted using one-way ANOVA and Tukey multiple comparison tests (α=.05). **RESULTS.** There were no statistically significant differences in the shear bond strength between the control group and the light curing, pressure, and oxygen inhibition groups. However, the heat treatment groups showed statistically higher bond strengths than the groups treated without heat, and the groups treated at a higher temperature resulted in higher bond strengths. Statistically significant differences were seen between groups after different degrees of heat treatment, except in groups heated at 100ºC and 140ºC. **CONCLUSION.** Strong bonding can be achieved between a bis-acryl base and bis-acryl repair material after heat treatment. ***[J Adv Prosthodont 2015;7:47-50]***

KEY WORDS: Bis-acryl; Repair; Relining; Heat; Shear bond strength

INTRODUCTION

Materials commonly used to fabricate provisional restorations include polyethyl methacrylate (PEMA), polymethyl methacrylate (PMMA), polyvinyl methacrylate, and bis-acryl. Among these materials, bis-acryl resin has become popular as a material for provisional restorations because it is convenient to use, delivers a low exothermic reaction, and causes less polymerization shrinkage.[1,2]

In general, the chemical similarity between materials being bonded has a great effect on the bond strength between the polymers involved.[3] Therefore, employing a repair resin that is chemically similar to the provisional base appears to deliver a higher bond strength than that of other materials that have a dissimilar composition.[3] However, in contrast to this rationale the bond strength between bis-acryl and bis-acryl is considered weak,[4] and the difficulty of using it in repair is therefore seen to be a critical shortcoming of bis-acryl resin. To overcome this limitation, some authors have suggested the use of light-cured flowable composites as a repair material for bis-acryl provisional restoration. Hagge *et al.*[4] showed that air abrasion, followed by

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the application of a flowable composite, can be a successful method of repair for use with bis-acryl composite. Through case reports, Bohnekamp and Garcia,[5] and Hammond *et al.*[6] demonstrated efficacy of the use of flowable composite as a method of bis-acryl provisional restoration, although the resistance of the repaired composite to fracture using this method has still not yet been proven.[3]

Repairing a provisional bis-acryl restoration using bis-acryl would simplify the process of repair, and the bond strength of the repaired material would be expected to surpass that of bis-acryl and flowable composites. However, no reports have yet determined a method to achieve strong bond strength between bis-acryl resins. The purpose of this *in vitro* study is therefore to determine an appropriate way of increasing the bond strength between bis-acryl resins, by comparing the shear bond strength between bis-acryl resins obtained using different treatments involving light curing, pressure, oxygen inhibition, and heat.

MATERIALS AND METHODS

Self-curing bis-acryl resin (Luxatemp AM Plus, DMG, Hamburg, Germany; shade A2, Lot 698382) was used as the base material and repair material. The shear bond strength test required the use of a sample holder to fix the specimen in the universal testing machine, perpendicular to the orientation of the shear force, and transparent acrylic glass rods (Polymicar, Tae-guang, Korea) were fabricated for this purpose. The mixed self-curing bis-acryl resin was dispensed into a 12-mm-wide hole in the acrylic glass rod and was allowed to set for 10 minutes.

Prior to repair, the surfaces of the specimens were ground with silica carbide (SiC) paper (grit 180), rinsed with water for 10 seconds, and dried for 30 seconds using an air syringe. Hard transparent gelatin capsules (4.0 mm in diameter) were used as matrices for the production of columns of relining materials bonded to the bis-acrylic provisional resin surface. The capsule was partially filled with repair materials to limit the thickness of the bonded material to 2 mm (Fig. 1).

Immediately after specimen preparation, the specimens were treated in the following different ways for 20 minutes: CONTROL - room temperature without any treatment, LIGHT CURING - exposed the top surface of the specimen to a light curing unit (Drs light, Good Doctors Co., Jungcheon, Incheon, Korea), PRESSURE - stored in a pressure cooker (PSPC-24C, PN Poongnyun, Danwon, Ansan, Korea) without waater at 0.2 Mpa, OXYGEN INHIBITION - applied an oxygen inhibitor (Oxyguard II, Kuraray Noritake Dental Inc., Kurashiki, Okayama, Japan) around the repaired material, and HEAT - applied heat using a dry oven (WiseVen, Daihan Scientific Co., Yeong-deungpo, Seoul, Korea) at 60ºC, 100ºC, or 140ºC. Each group involved 10 specimens and Table 1 describes the groups tested.

After the treatments were applied, the shear bond strength was measured with a universal testing machine (AG-10KNX, Shimadzu Co., Kyoto, Japan). A knife-edge shearing rod was used at a crosshead speed of 1 mm/min to place a load on the specimens until fracture occurred. The shear bond strength (MPa) was calculated from the peak load of failure. The aspect of each bonding failure was determined and recorded using a video measuring system (Optical video measuring system, Seven Ocean, Seoul, Korea) at 10× magnification.

The mean and standard deviation of the shear bond strengths were calculated for each treatment group. The data was evaluated for homogeneity of the variance based on the Levene test (α=.05). A comparison of the bond strength between repaired specimens was conducted by one-way ANOVA and Tukey multiple comparison tests (α <.05). All statistical analyses were carried out with SPSS for Windows (release 12.01; SPSS Inc., Chicago, IL, USA).

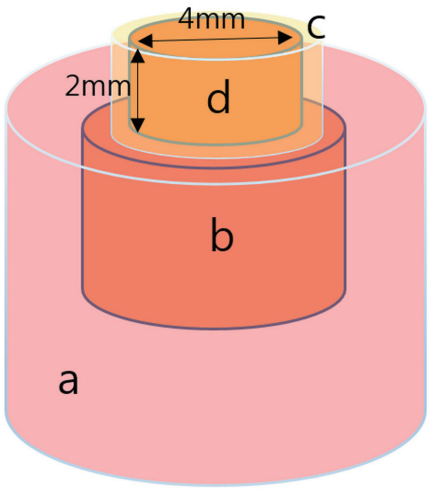

Fig. 1. Schematic figure of specimen; a- acrylic glass rod, b- bis-acryl base material, c- gelatin capsule, d- bis-acryl repair material.

Table 1. Design of the experiments

Methods	Group (Number of specimen)
Control	Group 1 (10)
Light-curing	Group 2 (10)
Pressure	Group 3 (10)
Oxygen inhibition	Group 4 (10)
Heat (60°C)	Group 5 (10)
Heat (100°C)	Group 6 (10)
Heat (140°C)	Group 7 (10)

RESULTS

The results of the shear bond strength for each experimental group are summarized in Fig. 2. The detachment results for the groups treated at room temperature indicates that group 3 (pressure) had the highest shear bond strength followed by group 4 (oxygen inhibition), group 2 (light curing), and group 1 (control). However, there were no statistically significant differences between the groups treated at room temperature.

The heat treatment groups (Groups 5-7) showed statistically higher bond strengths than the groups treated without heat (Groups 1-4), and the groups treated at a higher temperature resulted in higher bond strengths. There were also statistically significant differences between group 5 (heat/60ºC) and group 6 (heat/100ºC) ($P<.05$), but there were no statistically significant differences between group 6 (heat/100ºC) and group 7 (heat/140ºC). There was a burn odor recorded during heat treatment at 140ºC, but there was no trace of burn on the specimen. All of the groups treated at room temperature (Groups 1-4) showed adhesive failure and all of groups subjected to heat treatment (Groups 5-7) showed cohesive failure. Most cohesive failures took place in the base material of the specimens, but four specimens of group 7 (heat/140ºC) showed cohesive failure of the repaired material.

DISCUSSION

There is little available information concerning methods to increase the bond strength of dental composites especially for bis-acryl resin, but light curing,[7] pressure,[8] oxygen inhibition,[9] and heat[10] have been proposed to fortify the mechanical properties of resin composites. Therefore, to achieve the purpose of this *in vitro* study, finding the way to increase the bond strength between bis-acryl resins, light curing, pressure, oxygen inhibition and heat was selected as variables of the experiment.

The effects of light-curing, pressure, oxygen inhibition, and heat treatments on the shear bond strength between bis-acryl composites were evaluated. Among the above identified treatment methods, only the application of heat had an effect on the shear bond strength between bis-acryl resins and strong bond strength could be achieved using heat treatment after 20 minutes of bonding.

Although there are few available studies involving the heat treatment of bis-acryl, investigations of the heat treatment of other dental resins showed that increasing wear resistance,[11] tensile strength,[12,13] fracture toughness[14] and hardness[15] were obtained by applying heat treatment. These reports concluded that the increased mechanical properties resulting from heat treatment was related to an increase of the degree of cure. Therefore, the effect of heat treatment on dental resins prompts the degree of cure. The degree of cure of bis-acryl is lower than other provisional restoration materials[16] and it can be improved more than other provisional restoration materials by heat treatment. In conclusion, the dramatic increase in bond strength between bis-acryl obtained by heat treatment in this study seems to be related to the low degree of cure of bis-acryl and the accelerated cure of bis-acryl by heat treatment.

The optimal heat treatment for composite resin was 125ºC for a total of 7.5 minutes,[17] but there is no available information about the proper heat temperature for the treatment of bis-acryl. In our study, there were no significant differences between the groups heat-treated at a temperature of 100ºC and groups treated at a temperature of 140ºC. During heat treatment at 140ºC, a burning odor was smelt and only specimens heat-treated at 140ºC showed cohesive failure of the repaired material. Therefore, it can

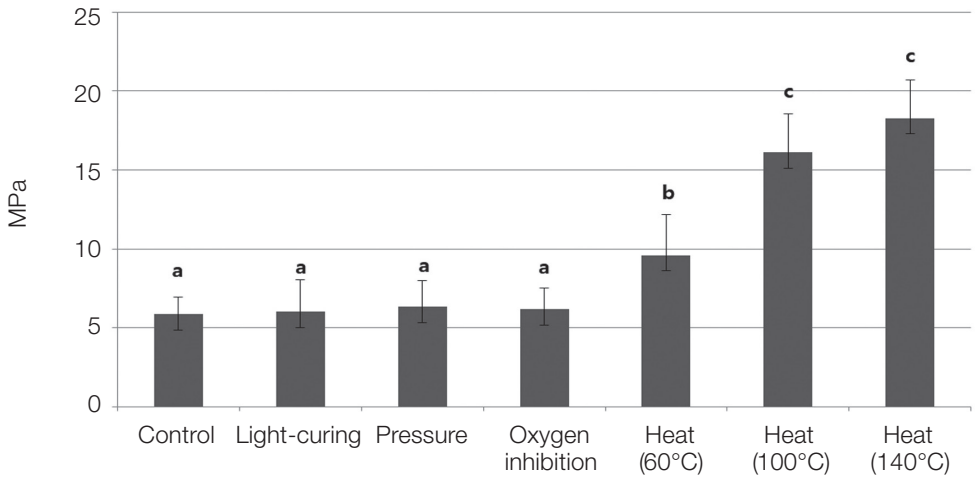

Fig. 2. The bond strengths of the each repaired materials, groups with the same letter did not show any statistically significant differences ($\alpha>.05$).

be assumed that the strongest bonding between bis-aryl resins was achieved from heat treatment around a temperature of 100ºC for a time period of 20 minutes and the chemical deformation of bis-acryl occurred at a heat treatment temperature between 100ºC and 140ºC.

Ferracane and Condon[18] showed that shorter heat treatment was sufficient to enhance the mechanical properties of a composite resin compared to heat treatment for different durations (3 hours and 10 minutes) at the same temperature (120ºC). The duration of heat treatment is also an important factor, although it was not considered in this study. Indeed, although a strong bond between bis-acryl resins was achieved through heat treatment of 20 minutes, there are concerns about shrinkage and deformation of bis-acryl resin due to the heat treatment. Therefore, in order to apply the results of this study to the clinical setting, more data regarding time factors of heat treatment and the other effects of heat on the mechanical properties of bis-acryl resin are required.

CONCLUSION

Light curing, pressure, and oxygen inhibition have no effect on the shear bond strength between bis-aryl resins. However, higher bond strength between bis-acryl resins can be achieved using the heat treatment of 100ºC for 20 minutes.

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A torque-measuring micromotor provides operator independent measurements marking four different density areas in maxillae

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PURPOSE. Bone density at implant placement site is a key factor to obtain the primary stability of the fixture, which, in turn, is a prognostic factor for osseointegration and long-term success of an implant supported rehabilitation. Recently, an implant motor with a bone density measurement probe has been introduced. The aim of the present study was to test the objectiveness of the bone densities registered by the implant motor regardless of the operator performing them. **MATERIALS AND METHODS.** A total of 3704 bone density measurements, performed by means of the implant motor, were registered by 39 operators at different implant sites during routine activity. Bone density measurements were grouped according to their distribution across the jaws. Specifically, four different areas were distinguished: a pre-antral (between teeth from first right maxillary premolar to first left maxillary premolar) and a sub-antral (more distally) zone in the maxilla, and an interforaminal (between and including teeth from first left mandibular premolar to first right mandibular premolar) and a retroforaminal (more distally) zone in the lower one. A statistical comparison was performed to check the inter-operators variability of the collected data. **RESULTS.** The device produced consistent and operator-independent bone density values at each tooth position, showing a reliable bone-density measurement. **CONCLUSION.** The implant motor demonstrated to be a helpful tool to properly plan implant placement and loading irrespective of the operator using it. ***[J Adv Prosthodont 2015;7:51-5]***

KEY WORDS: Bone density; Immediate dental implant loading; Osseointegration

INTRODUCTION

Implant primary stability at implant placement plays a pivotal role in determining the osseointegration of the fixture and therefore its long-term success.[1] Primary stability is affected by different factors: bone quantity, implant geometry and surgical technique.[2] A correct assessment of the anatomical conditions at the placement sites guides the choice of the best implant site preparation approach and of the most appropriate loading protocol among immediate, early or delayed.[3] Computed tomography (CT) or cone beam computed tomography (CBTC) scans provide a detailed evaluation of the implant placement site anatomy, and therefore a precise assessment of the bone quantity and quality available at the site itself. Nevertheless, both techniques seem to be still not sufficiently reliable in measuring bone density. CT scans seem to provide a reliable quantitative pre-surgical measurement of the bone density around the implant sites,[4] but concerns have been expressed about the reproducibility of the technique.[5,6] Attempts of getting reliable numerical bone density measurements from cone-beam CT scans have been made,[7] but it has been found that results, are affected by the CT unit and even by the Field of View (FOV) of the unit itself.[8,9]

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The only reliable numerical measurement of bone density at implant sites is the histomorphometric assessment, although it is unfeasible as it requires a bone biopsy and therefore it cannot be used intra-operatively.

For the reasons listed above, measurements of bone density at implant sites still relies on subjective assessments, as described by the most common classifications, namely the ones by Lekholm and Zarb,[10] or by Misch[11] with further changes introduced by Trisi and Rao.[12] However, such classifications suffer from being empirical and subjective, and moreover, they have a limited utility in the diagnosis as they are performed at the time of implant placement. Recently, an intra-operatory bone density measuring system has been introduced; it is a bone measuring density probe provided with an implant motor unit.[13] The unit is endowed with an instantaneous torque measuring system. Such a torque is a function of the friction exerted by the tunnel bone walls; indeed, the average torque along the whole tunnel is significantly correlated with the bone density of the surrounding bone wall, as it has been shown by a recent study on bovine ribs.[13] When used in a clinical context, 1254 bone density measurements in 464 patients showed the device allowed the distinction of anatomic areas with different bone densities, namely IDI1-4 (Intra-operatory Density Index) from the more to the less dense.[14] If the repeatability of measurements with such device were confirmed, it would represent an invaluable tool to perform a proper intra-operatory diagnosis of bone density and therefore, to adapt the implant site preparation accordingly. However, the measurements could be operator-dependent, thus providing useful but still subjective assessment. The aim of the present study was to test the inter-operator repeatability in order to validate the objectiveness of the bone density values recorded by this system.

MATERIALS AND METHODS

Thirty-nine operators were provided with a bone density measurement unit, namely a TMM2 implant motor (IDI Evolution, Concorezzo, Italy) and they, independently, collected 3704 bone density measurements of implant placement sites. When a bone density measurement was performed a measuring probe was mounted on the handpiece. The probe was a 2 mm wide cylinder featuring equally spaced threads, whose width was 3 mm and shape was a 1-degree reverse cone (patented, Fig. 1). At tunnel preparation, the surgeons first created a 2.2 mm round hole for the whole depth of the cortical bone layer, and subsequently used a 2.3 mm bur to drill a first, narrow tunnel, till the desired implant placement depth. Before enlarging the tunnel to its final width, in order to standardize the bone density measurement procedure and permit further statistical comparison among homogeneous data, operators were instructed to use a bone reamer to drill a 3 mm deep, 3 mm wide, circular access hole, thus eliminating the first overdense cortical bone ridge layer. After mounting the probe on the handpiece, and switching it in its measurement mode, the first probe thread was inserted in the access hole. The surgeons proceeded to switch on rotation and let the probe screw itself into the previously prepared tunnel, without exerting any additional pressure (Fig. 2). The upside-down cone shape of the threads allowed the device to measure the friction encountered by the first thread only. When the device was in its measurement mode the probe rotated at a given speed (30 rpm) and could reach 35 Ncm maximum torque. While the probe deepened into the tunnel, digital software performed a high frequency sample measurement of the instantaneous torque needed to keep the speed constant. The device recorded also the depth the probe had reached, given the fact probe threads were evenly spaced, and their pitch was known. The device, calibrated with high-precision dynamometers, automatically performed a self-calibration routine at each switching on. The device displayed a torque/depth graph as an output showing how the instantaneous torque had varied according to the probe depth (Fig. 3). During measurement average torque and curve integral were calculated and displayed together with the peak torque on the device display.

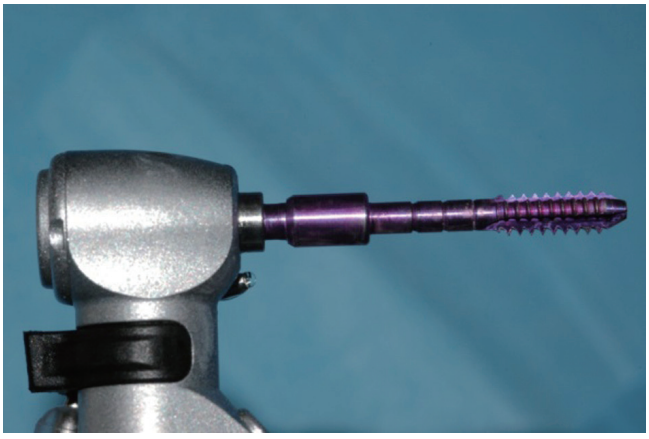

Fig. 1. The bone density measurement probe.

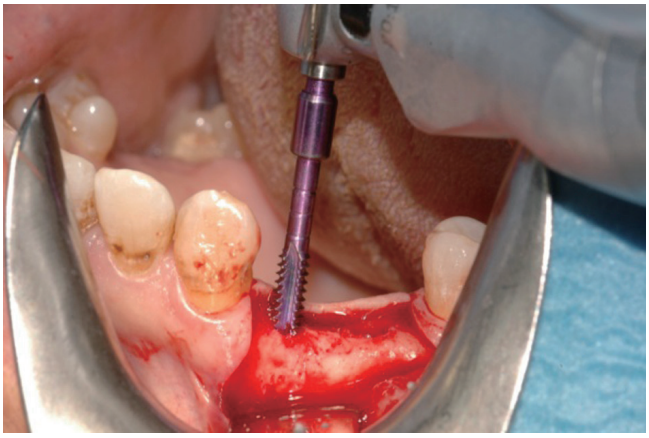

Fig. 2. At measurement, the probe deepens into a 2.3 mm diameter tunnel at the placement site.

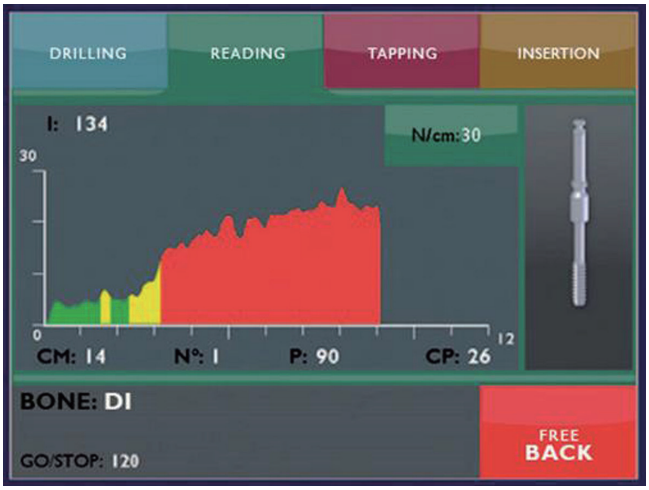

Fig. 3. The torque/depth plot generated by the device. I = integral (corresponding to the area below the curve); CM = average torque; N = progressive measurement number; P = depth; CP = maximum torque. GO/STOP = pre-set depth the probe stops at.

Data were recorded in the device solid state memory to be downloaded to a common PC for statistical analysis.

Mean torque measurements collected by each operator were compared applying the Kruskall-Wallis test at a confidence level of *P*=.05. Statistical analysis was performed with standard analysis software (Origin 9.0, Microcal, Northampton, MA,USA).

Further analysis was performed as follows: four anatomic zones were defined, namely a pre-antral (the upper anterior teeth from first right maxillary premolar to first left maxillary premolar) and a sub-antral (more distal) zone in the upper maxilla, and an interforaminal (the lower anterior teeth from first left mandibular premolar to first right mandibular premolar) and a retroforaminal (more distal) zone in the lower one.

Data from each operator were pooled according to the position in the four–zones identified above to get an average density value for each given zone. Then the two average density values corresponding to the distal and mesial zones of a given arch (upper or lower) were compared through a two-tail t-test at *P*=.05 (sub-antral versus pre-antral, retroforaminal versus interforaminal). With the same statistical approach, bone density values of corresponding upper and lower regions of the jaws were compared (pre-antral, versus interforaminal, sub-antral versus retroforaminal). Additionally, the bone density values corresponding to the overall means of the measurements assessed in the mandible and in the maxilla were calculated and compared with a two samples, two-tails, t-test (*P*=.05). All values were given as mean ± standard error of mean (s.e.m).

RESULTS

Single bone density measurements were not shown for the sake of brevity. No statistical differences among the measurements recorded by the 39 operators were detected (Table 1), indicating that the measurements provided by the device were operator-independent.

Statistically significant differences were found when comparing the mean bone density values in the four pre-set jaw regions (Fig. 4). Moreover, statistically significant differ-

Table 1. Statistical comparison of the data recorded by the different operators in the implant placement sites

Arch	Implant placement sites	*P*
Upper	# 18, 28	NA
	# 17, 27	.43[a]
	# 16, 26	.39[a]
	# 15, 25	.51[a]
	# 14, 24	.45[a]
	# 13, 23	.51[a]
	# 12, 22	.16[a]
	# 11, 21	.42[a]
Lower	# 31, 41	.37[a]
	# 32, 42	.12[a]
	# 33, 43	.62[a]
	# 34, 44	.24[a]
	# 35, 45	.14[a]
	# 36, 46	.45[a]
	# 37, 47	.54[a]
	# 38, 48	NA

NA: not available, [a]: not significant.

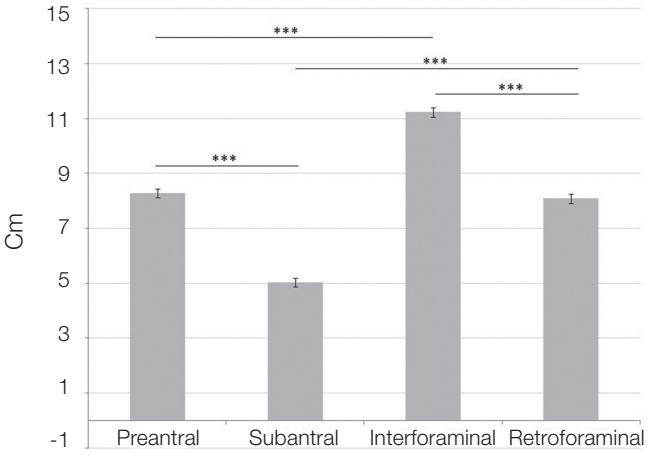

Fig. 4. Statistical comparison of overall means of bone density measurement collected in the four anatomical zones, a pre-antral (anterior) and a sub-antral (posterior) zone in the upper maxilla, and an interforaminal (anterior) and a retroforaminal (posterior) zone in the lower jaw.
*: statistically significant difference
Cm: average torque

Table 2. Bone Density at four different positions in the jaws

Overall means of bone density measurements collected in the four anatomical zones, a pre-antral and a sub-antral zone in the upper maxilla, and an interforaminal and a retroforaminal zone in the lower jaw.

Anatomical zones	N	Cm (mean ± s.e.m.)	
Pre-antral (UA)	1023	8.28 ± 0.15	6.98 ± 0.12
Sub-antral (UP)	681	5.03 ± 0.16	
Interforaminal (LA)	933	11.23 ± 0.17	9.56 ± 0.12
Retroforaminal (LP)	1067	8.09 ± 0.17	

N: total number of bone density measurements. Cm: average torque.

ences were found when comparing the overall bone density values of the maxilla vs mandible (Table 2, fourth column).

DISCUSSION

"Implant success strictly relies on the correct evaluation of bone density at implant placement site, which is a strong predictor of primary stability and allows to make proper decisions about site preparation and the immediate loading protocol viability.[15,16]

The device used in the present study has already been shown to provide reliable bone density measurements, with a significant correlation with histomorphometric data,[13] and to distinguish pre-defined zones with different bone densities.[14] In addition, the present investigation showed that the system provides objective, operator-independent measurements, not based on subjective perception as current classifications do, thus allowing to adjust the site preparation according to the results of the measure. Clinical consequences could be of high interest. The availability of an objective measurement of bone density at the placement site enables a reliable intra-surgical diagnosis of bone density, and could affect clinical practice positively in two ways. Firstly, a reliable rationale for tunnel preparation could be formulated, providing well-defined criteria for under-preparation at low-density sites. Secondly, the availability of a torque-depth graph, showing how bone density varies along the implant placement site, could lead to further refinements of the implant placement strategy also in relation to the loading protocol (delayed vs. early or immediate), or even to come to a definitive decision about the loading protocol itself after implant placement, according to actual, objective bone density values recorded with the device. Further studies should be aimed to formulate such criteria. It is worth noticing that the device allows measurement of the same quantities (i.e., average and peak torque values, and torque-depth curve integral) also at implant insertion, providing additional data about implant primary stability and about the implant-bone relation at site of placement. Further studies should also be aimed to investigate if loading protocols may be adjusted according to the measurements recorded at implant insertion.

CONCLUSION

The intraoperative bone density measurement system showed to provide operator-independent results, thereby representing a significant and reliable aid for surgeons for a proper preparation of the implant tunnel and as a useful research tool.

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