

Results of Using Dental Implants Manufactured by Direct Metal Laser Sintering (DMLS) After the Surgical Stage of Dental

Summary.

Extensive clinical experience with dental implants has shown that the topography and roughness of the implant surface play a key role in many cellular and molecular mechanisms, significantly contributing to the speed and quality of osseointegration. As a solution to the challenge of creating a porous structure with a fully controlled design of both the external shape and internal architecture, manufacturers have proposed the use of additive manufacturing of dental implants using Direct Metal Laser Sintering (DMLS). By comparing radiographic findings, insertion torque, and measuring implant primary stability (ISQ), we have evaluated the clinical outcomes of using DMLS-manufactured dental implants after the surgical phase of implantation, in comparison with traditional milled implants.

Keywords.

Dental implants, DMLS, torque test, Alpha Dent Superior Active, Alpha Dent Cell.

Introduction.

Dental implantation, as a method of treating secondary edentulism, has shown a consistent growth trend since its invention. The process of osseointegration, defined as a direct structural and functional connection between organized living bone and the implant surface, is the foundation

of the global popularity of this technology. This biological phenomenon enables a foreign body to exist stably within a living organism, withstand significant mechanical loads, and achieve long-term clinical success — ultimately leading to patient satisfaction.

Since the properties of the implant surface have long been studied and characterized as a crucial factor in promoting osseointegration [1,2], current research is focused on optimizing the surface potential for osteon integration. Currently, the most widely used dental implants are those manufactured by mechanical processing of titanium rods, followed by surface modifications such as sandblasting [3], acid etching [4,5], anodization [6,7], and discrete deposition of calcium-phosphate crystals [8]. These surface treatment methods are aimed at improving implant stability and enhancing osseointegration [1–9].

Extensive clinical experience with dental implants has demonstrated that the surface topography of the implant plays a key role in many cellular and molecular mechanisms.

Rough surfaces have shown better adsorption of biomolecules from biological fluids, which initiate a cascade of biological events that regenerate bone, enhance the initial cellular response, including cytoskeletal organization and cell differentiation [1–3, 8, 9]. Histological studies have confirmed that

rough surfaces more effectively promote the rate and quality of osseointegration compared to untreated surfaces. There are studies that clearly demonstrate significantly higher success rates in dental implantation using implants with roughened surfaces [5, 7, 10, 12, 13].

According to current concepts of osseointegration, it has been established that the optimal surface roughness for bone tissue ingrowth occurs when the distance between structural peaks and pore sizes ranges between 200–400 μm [11]. Since osseointegration is a key factor in the success of dental implants, the use of porous implants can be biologically justified, as it expands their function by promoting integration throughout the entire implant body. Improved fixation can be achieved by bone tissue growing into or through the porous structure of the implant, thereby connecting not only to the rough surface but also to the entire implant volume. However, from a mechanical standpoint, this implant–bone connection must be sufficiently rigid to withstand the mechanical load applied by the prosthetic construction.

Classical manufacturing methods do not allow for the production of porous structures with fully controlled external shape and internal architecture. Therefore, additive manufacturing methods for dental implants have been proposed as a solution to this limitation [14, 15]. This approach of directly generating physical objects with defined structures and shapes based on three-dimensional

modeling opens a broad field for studying the processes of osseointegration of printed implants in a living organism.

Objective.

To study the experience of using dental implants manufactured by Direct Metal Laser Sintering (DMLS) after the surgical stage of dental implantation, in comparison with conventionally milled implants.

Tasks.

- Determine the difference in the insertion torque (torque force) between implants manufactured by Direct Metal Laser Sintering (DMLS) and those produced by the conventional milling method during installation.
- Compare the primary stability of dental implants made by DMLS and the conventional method by measuring ISQ (Implant Stability Quotient) values.
- Investigate the radiological pattern of osseointegration of dental implants produced by DMLS and those produced by the conventional method.
- Analyze the clinical experience of using dental implants manufactured by Direct Metal Laser Sintering (DMLS).

Materials and Methods.

The study involved 22 participants (aged 22–54, both male and female) who received at least two adjacent dental implants of the same size simultaneously. The first implant was manufactured using the conventional machining method, including sandblasting and acid-etching surface treatment. The second implant was

produced via layer-by-layer Selective Laser Melting (SLM).

The DMLS implants were fabricated using additive manufacturing technology, where titanium powder was melted layer by layer, with each layer growing vertically in the direction of functional load. The implants were made of Grade 4 titanium alloy powder, with a particle size of $45 \pm 10 \mu\text{m}$, using 30 nm-thick layers fused by two 200 W fiber lasers (wavelength: 1070 nm). The manufacturing was carried out using the Trumpf TruPrint 1000 system. Samples of Alpha Dent Superior Active implants (21 samples) and Alpha Dent Cell implants (21 samples) were used in the study. The surface treatment process for both types of implants was identical, featuring a wet SLA surface. The primary stability of all implants was measured using ISQ values, as well as insertion torque values. Implant torque was measured using a torque wrench at the time of implant placement. ISQ values were recorded using the Penguin RFA device at the time of implantation, and on days 15, 30, and 60. In some cases, healing abutments were immediately installed. Intraoral contact radiography was performed using the Pluto Super HD radiovisiograph. Radiographic evaluations were carried out at the time of implantation, and on days 30 and 60.

Research Results

1. Determination of the difference in insertion torque between implants manufactured using Direct Metal Laser Sintering (DMLS) and those produced

using the conventional machining method during their placement.

It should be noted that the torque value is crucial when making decisions regarding the placement of a healing abutment or the application of early prosthetic loading. Therefore, achieving high insertion torque is a priority for the implantologist. At the time of implant placement, we recorded the insertion torque values in Newton centimeters (N·cm). The obtained data are presented in Table 1.

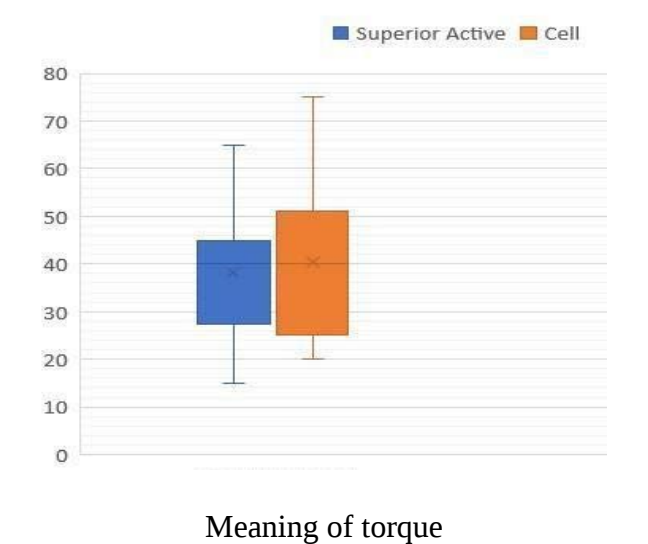


Table 1. Insertion Torque Values at the Time of Placement for Different Types of Implants of Identical Size

Different bone types in patients of various age groups and sexes resulted in data heterogeneity; however, it should be noted that in almost all patients, under identical conditions, the torque value was higher in the printed samples (Cell implants), indicating a greater total surface area of the implant. In the maxilla, the torque values were comparatively lower than in the mandible, which can be

explained by the biological characteristics of the jawbone structure.

The only drawback of the torque test is the inability, for obvious reasons, to perform follow-up measurements at different stages of osseointegration. Nevertheless, this method provides comprehensive insight into the implant–bone interaction at the time of placement.

2.Comparison of the stability of dental implants manufactured by direct metal laser sintering (DMLS) and those produced by conventional methods based on ISQ measurements.

All patients who received dental implants had their ISQ values recorded using the Penguin RFA device at the time of implantation, as well as on days 15, 30, and 60 (Table 2). The collected data showed that in most cases, ISQ values increased during the first 14 days, likely indicating the effect of trabecular expansion in the spongy bone layer. Between days 14 and 30, a decrease in ISQ values was observed, which may reflect osteoclast activation and active remodeling of the bone matrix around the implant. From day 30 to day 60, there was a noticeable increase in implant stability.

It is important to note that the rate of stability increase at this stage likely confirms the quality of interaction between the implant surface and osteoblasts, which, during this period, begin transforming the previously formed protein matrix into immature bone tissue. In our opinion, it is the non-traditional design of the Cell

implants, combined with their active hydrophilic surface (implants stored in a buffered solution without oxygen exposure), that allowed for earlier activation of the osteoblast-osteoclast complex and led to reduced osteointegration timeframes.

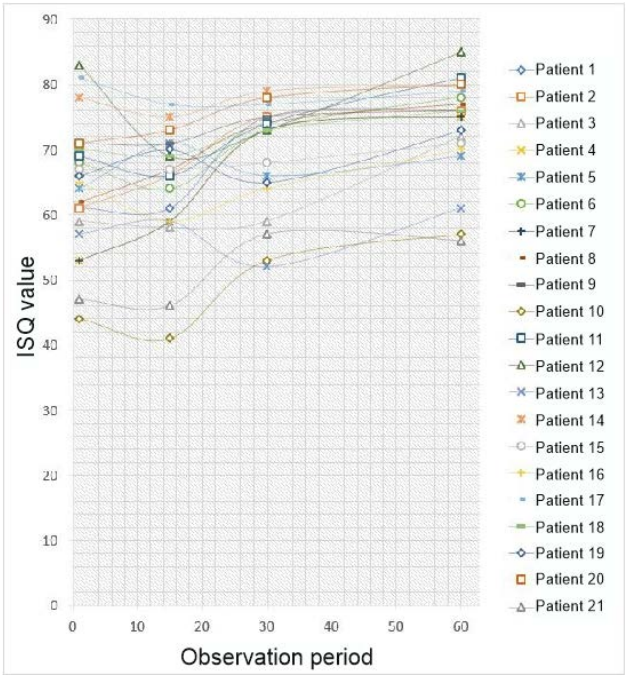


Table 2. Summary of Cell Implant Stability Values at Different Observation Stages (ISQ Test)

3. Radiographic Assessment of Dental Implants Manufactured by Direct Metal Laser Sintering and Conventional Methods at the Stages of Osseointegration

Intraoral contact radiography enables an objective assessment of the bone pattern surrounding the implant and serves as a key method in diagnosing and predicting early complications in dental implantation. Throughout the observation period, no complications were noted in any patient. Radiographic evaluations were performed at the time of implantation, as well as on the

30th and 60th day. The radiographic images exhibited a consistent, uniform appearance, with minimal changes observed even after prosthetic loading (Fig.1). The presence of well-defined implant contours without signs of reduced radiodensity at the bone-implant interface indicates true osseointegration.

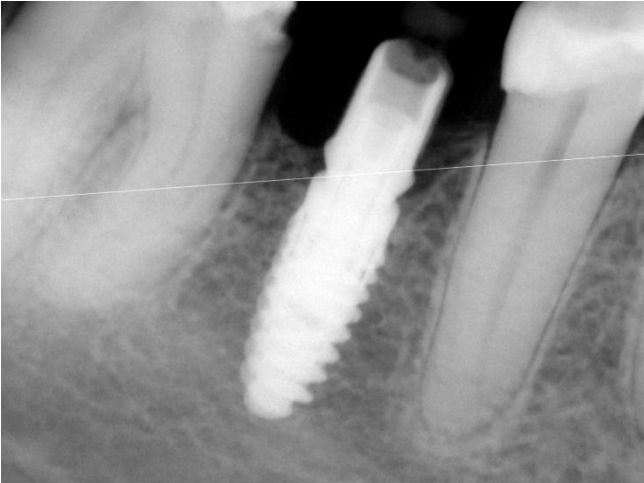


Figure 1. Radiographic image of the printed Alpha Dent Cell implant with a provisional crown.

Conclusions.

Based on the analysis of the data presented above and comparing different types of implants, a number of interesting conclusions can be drawn. The insertion torque values in all pairs of studied implants were similar, which can be explained by identical bone conditions and equal implant dimensions. The average torque values ranged from 25 to 55 N/cm². No statistically significant differences were recorded. However, it is worth noting that under identical conditions, slightly higher torque values were achieved with the use of Cell implants.

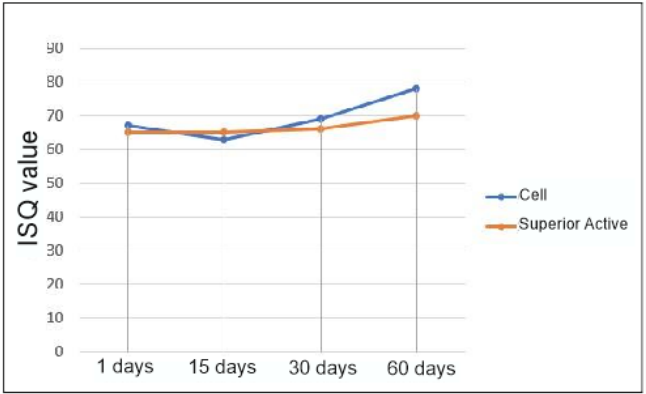


Table 3. Comparison of average ISQ values of implants manufactured using the conventional method (Superior Active) and the DMLS method (Cell).

The ISQ test demonstrates similar values between the compared implant samples; however, particular attention should be given to the dynamic increase in ISQ values between days 20 and 60. This indicates the contribution of the printed implant body framework, which, due to its more developed surface area in contact with the bone, results in faster and higher-quality osseointegration. This is also radiologically confirmed.

It is especially important to note that the compared implants both featured an active wet surface, which has been proven to be more effective than the traditional SLA surface used in most implants [16]. Therefore, it can be assumed that, when compared to conventional implants with a dry surface, the difference would be even more significant — which sets the foundation for future research.

In conclusion, after studying the clinical experience of using dental implants manufactured using the Direct Metal Laser Sintering (DMLS) method in comparison with conventionally milled samples, we

can state the promising nature and clinical advantages of DMLS implants.

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