Review Article

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The possibility of full-arch rehabilitation for edentulous patients supported by 4 dental implants

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Abstract

AIM. The objective of this study is to review possible methods of fixed prosthesis for patients with complete edentulousness using 4 dental implants.

RESULTS. Patients with complete edentulousness and significant alveolar bone atrophy often complain about unsatisfactory fixation of complete removable dentures. Dental implantation is used to make prostheses with stable fixation. Full fixed prostheses supported by 6–8 dental implants have the greatest stability and strength indicators, however, in some cases, with significant bone atrophy, the placement of a large number of implants is impossible. The “All-on-4” technique was proposed to accelerate the rehabilitation of elderly edentulous patients, which allows making fixed prosthesis supported by 4 dental implants without bone grafting procedures. This treatment method involves the installation of distal implants at an angle to the frontal plane in order to position the prosthetic platforms in the premolar area, which reduces the length of the distal console elements and distributes the occlusal load more evenly.

CONCLUSIONS. The “All-on-4” technique has become widespread among dentists due to its relative ease of performance, low cost and quick rehabilitation of edentulous patients. This treatment method shows high survival and success rates, and thus can be an effective alternative to placing more implants. However, this method of treatment requires further study from the point of view of functional changes of the dento-alveolar system in patients with complete absence of teeth and justification using the methods of electromyography of masticatory muscles and digital analysis of occlusion, as well as determination of critical values of angles of inclination of distal implants using the method of mathematical modeling.

Keywords: implant, edentulousness, atrophy, prosthesis, All-on-4

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Возможности несъемного протезирования пациентов с полным отсутствием зубов с опорой на 4 дентальных импланта

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Резюме

ЦЕЛЬ. Обзор метода несъемного протезирования пациентов с полным отсутствием зубов с использованием 4 дентальных имплантатов.

РЕЗУЛЬТАТЫ. Пациенты с полным отсутствием зубов и выраженной атрофией альвеолярной кости при использовании полных съемных протезов часто предъявляют жалобы на их неудовлетворительную фиксацию. С целью улучшения фиксации протезов применяется метод дентальной имплантации. Наибольшей устойчивостью и прочностными свойствами обладают полные несъемные протезы с опорой на 6–8 дентальных имплантатов, однако в ряде случаев при выраженной атрофии костной ткани установка большого количества имплантатов невозможна. С целью более быстрой реабилитации беззубых пациентов с выраженной атрофией альвеолярной кости, а также пациентов с соматической патологией, была предложена методика «All-on-4», позволяющая изготовить несъемный протез с опорой на 4 дентальных имплантата, не прибегая к обширным костно-пластическим операциям. Данный метод лечения предполагает установку дистальных имплантатов под углом к фронтальной

плоскости с целью расположения ортопедических платформ в области премоляров, что позволяет уменьшить длину дистальных консольных элементов и более равномерно распределить окклюзионную нагрузку.
ВЫВОДЫ. Методика «All-on-4», получила широкое распространение среди стоматологов вследствие относительной простоты выполнения, дешевизны и быстроты реабилитации беззубых пациентов. Этот метод лечения демонстрирует высокие показатели выживаемости и успешности, а значит, может быть эффективной альтернативой установке большего количества имплантатов. Однако, данный метод лечения требует дальнейшего изучения с точки функциональных изменений зубочелюстной системы у пациентов с полным отсутствием зубов и обоснования с использованием методов электромиографии жевательных мышц и цифрового анализа окклюзии, а также определения критических значений углов наклона дистальных имплантатов с помощью метода математического моделирования.

Ключевые слова: имплантат, адентия, атрофия, протезирование, All-on-4

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INTRODUCTION

According to the World Health Organization, 29% of individuals aged 65–74 worldwide suffer from complete edentulism. This condition can be addressed through two principal prosthetic options: the fabrication of complete removable mucosa-supported dentures or the placement of prosthetic constructions supported by dental implants. The absence of teeth may lead to difficulties or inability to chew food, impaired social integration, and psycho-emotional discomfort due to compromised speech and esthetic deficiencies. Furthermore, long-term edentulism results in functional disturbances of the stomatognathic system, including temporomandibular joint dysfunction and altered masticatory muscle activity. The most significant disadvantage of removable mucosa-supported dentures is their inadequate retention, particularly in cases of pronounced alveolar ridge atrophy [1]. This can lead not only to mechanical damage of the prosthesis–such as fracture or increased wear of artificial teeth–but also to exacerbation of functional impairments. Nevertheless, the relatively low cost of such prostheses and the absence of additional surgical interventions make them an attractive solution, although every prosthetic method presents both advantages and significant limitations.

In contemporary dental practice, dental implants are widely used for the replacement of missing teeth to provide support for both removable and fixed prosthetic constructions. This has greatly expanded treatment possibilities for patients with complete edentulism [2]. Numerous studies have been published to determine the optimal number of dental implants required for full-arch rehabilitation. In a 2010 study, V.V. Korkin conducted a comparative analysis of the survival of prosthetic constructions with different numbers of supporting implants using the Schleicher–Nadan criterion, which evaluates the combined effects of tensile, compressive, and shear stresses. The highest biomechanical strength in the “fixed prosthesis–endosseous implants–alveolar bone” system was observed when six to eight vertically placed implants were used [3].

However, several anatomical characteristics of the maxilla, such as extensive pneumatization of the maxillary sinus and bone atrophy due to periodontitis and long-term tooth loss, often result in insufficient bone volume for the placement of six to eight dental implants, necessitating sinus augmentation procedures. On the mandible, vertical alveolar bone resorption progresses at an average rate of 0.2 mm per year. When combined with periodontal bone defects, this often requires bone grafting before implant placement. Performing extensive bone augmentation procedures in elderly patients with comorbidities carries an increased risk of complications. Moreover, in many cases, the actual bone volume gain after augmentation is minimal, which may necessitate repeated surgical intervention. For example, I. Urban, the author of the guided bone regeneration technique known as the “Sausage technique”, reports that additional augmentation is often required at the stage of implant placement within the previously regenerated area to ensure long-term volume stability [4].

Given these considerations, alternative treatment options to the placement of six to eight dental implants should be explored in specific clinical scenarios – one such alternative being the use of four implants in regions with favorable anatomic conditions. The fabrication of a fixed prosthesis supported by dental implants in cases of severe alveolar ridge atrophy requires careful planning of implant positioning and prosthetic design. One of the complications associated with fixed prostheses supported by four implants in fully edentulous patients is bone resorption around the implants caused by excessive loading resulting from altered stomatognathic function. According to D. Wismeijer, P. Casentini, G. Gallucci, and M. Chiapasco, the majority of cases of bone resorption and implant failure occurred in the distal segments, underscoring concerns regarding the long-term survival of fixed full-arch prostheses supported by only four dental implants [5].

Since the 1960s, standard Toronto-type implant-supported prostheses have been widely used in the treatment of edentulous patients, particularly in cases

of severe jaw atrophy. When four dental implants are used to support a fixed prosthesis, they are typically placed vertically in the anterior region of the mandible between the mental foramina. To avoid implant placement in the molar area, the distal cantilever extensions of such prostheses often reach lengths of up to 20 mm. However, cantilever lengths exceeding 15 mm are associated with a higher risk of complications, such as screw loosening, chipping of the veneering ceramic, framework fracture, significant bone resorption around the implants, and loss of osseointegration.

In his monograph, E. Agliardi cites Tulasne et al., who in 1989 proposed a protocol for placing 20–22 mm long implants into the pterygoid process of the sphenoid bone at an angle of 35–55 degrees. This approach was later modified: implants were instead placed in the pterygoid-maxillary region, parallel to the distal wall of the maxillary sinus, often without engaging the pterygoid process itself.

In 2000, Krekmanov et al. analyzed the effect of extending the prosthetic span of full-arch fixed restorations on both jaws by tilting the distal implants. This angulated implant placement allowed for better distribution of occlusal forces, reduction in the length of distal cantilevers, and improved implant survival rates within fixed prosthetic constructions. The survival rate of tilted implants reached 95.7%, compared to 90.2% for vertically placed implants, with no significant differences found in force and bending moments at the level of each implant [6]. As a result, tilted implant placement has become a well-established clinical practice and a viable alternative to bone augmentation procedures.

AIM

To review current approaches to fixed prosthetic rehabilitation in completely edentulous patients using four dental implants, including protocols involving the placement of tilted implants.

RESULTS

Between 2003 and 2005, P. Maló introduced the “All-on-4” protocol, which allows for the fabrication of a fixed full-arch prosthesis supported by four dental implants. In this technique, the two anterior implants are placed vertically in the region of the central or lateral incisors, while the two posterior implants are tilted at an angle of 30–45 degrees to the frontal plane in order to position the implant platforms in the region of the first or second premolars. This configuration avoids the need for bone grafting procedures and minimizes the risk of injury to critical anatomical structures. Tilting the posterior implants significantly reduces biomechanical forces and distributes occlusal load more efficiently than the use of five vertically placed implants. The prosthetic structure typically consists of a 12-unit acrylic prosthesis reinforced with a titanium framework, screw-retained onto multi-unit abutments.

In 2019, P. Maló published a retrospective long-term follow-up study on the “All-on-4” concept with an observation period ranging from 10 to 18 years. The study included 471 patients who received 1884 implants and 471 fixed prostheses. The primary outcome measures were prosthesis and implant survival rates, while secondary outcomes included marginal bone loss at 10 and 15 years, as well as biological and mechanical complications. A total of 176 patients (37%) were lost to follow-up. The cumulative prosthesis survival rate was 98.8%, and implant survival and success rates were 93% and 91.7%, respectively, over the 18-year observation period [7].

The relative simplicity of the procedure, reduced cost due to the absence of bone grafting materials, and growing global adoption of the “All-on-4” technique have inspired continued research. In a 2014 study by M. Taruna, B. Chittaranjan, and colleagues, which focused on the prosthetic success of the “All-on-4” method, particular attention was given to the angulation limits of distal implants, the length of cantilever extensions, and the importance of prosthetic framework reinforcement. When an implant is part of a splinted multi-implant framework, the rigidity of the prosthesis helps reduce implant bending. A more distal position of the posterior implant and a shorter cantilever can reduce stress on the implant. Theoretical models suggest that angulated implants allow for a longer prosthetic framework, which in turn reduces the forces acting on implants. From a biological perspective, the position of the prosthetic platform may be more critical than the actual angle of implant insertion.

Cantilever loading can create a hinge effect, generating high stress levels on the implants closest to the load. Excessive cantilever length may lead to deformation of the prosthetic framework and subsequent complications such as screw loosening, fracture of acrylic teeth, or even framework fracture. Splinted tilted implants demonstrate lower stress levels compared to vertically placed implants supporting a cantilever. Therefore, reducing prosthesis-induced stress may improve the longevity of full-arch fixed prostheses relative to traditional implant positioning. When vertical force is applied to the first premolar area of a tilted implant, adjacent implants share the load. Since the prosthesis is loaded between the anterior and posterior implants, the stress is distributed across both, without overloading the tilted implant.

Long-term studies have shown no significant differences in implant survival between maxillary fixed prostheses supported by four versus six implants. Stress distribution and loading patterns were comparable in four- and six-implant models. Cantilever length should be minimized, as long extensions significantly increase stress on distal implants regardless of the number of supporting implants. Finite element models examined deformation around distal implants angled at 0°, 15°, 30°, and 45°. No substantial differences were observed between the 0°, 15°, and 30° groups, although deformation increased at 45°. The recommended maximum cantilever length is 10–12 mm in the mandible and no more than 6–8 mm in the maxilla due to lower bone density [8].

Modern implant systems offer various implant–abutment connection designs, with the most common

being conical, internal flat-to-flat, and external hexagonal connections. In a 2023 study, Pei-Shuang Wang, Ming-Hsu Tsai, and colleagues performed a biomechanical evaluation of full-arch prostheses supported by four implants with different connection types. The implant–abutment connection type was identified as a factor influencing occlusal load distribution. Two groups were compared: one using implants with an external hex connection (4.0 mm diameter) and the other using conical connections (4.3 mm diameter). All components of the "All-on-4" protocol was included in the analysis–custom titanium frameworks, multi-unit abutments, fixation screws, and implants.

Precise measurements were taken using calipers and a digital microscope, and the models were additionally scanned with a 3D optical system (Aicon SmartScan-HE). CAD software and finite element analysis tools were used to create 3D models, which were embedded into a bone block model (50 mm × 30 mm × 40 mm) designed to mimic human bone, with a 3 mm dense outer cortical layer and an inner trabecular core. A vertical force of 190 N was applied at the distal cantilever of the framework.

Both groups showed similar stress levels and distribution on distal implants under identical load conditions. The highest von Mises stresses were recorded in the fixation screws, followed by the multi-unit abutments, indicating that these components are the most vulnerable in the distal implant zone. The lowest stress values were consistently found in the bone, with slightly higher bone stress in the external hex group compared to the conical group. Both groups showed a gradual decrease in von Mises stress from the multi-unit abutment to the implant collar. In the external hex group, stress was mainly concentrated on the screws and abutments, whereas in the conical group, the stress was more evenly distributed and slightly lower across the framework, screws, abutments, and bone tissue. Marginal bone resorption was higher in the external hex group, though the difference was not statistically significant. Therefore, both connection types are considered clinically suitable for the "All-on-4" protocol [9].

Despite the numerous studies devoted to the "All-on-4" technique–many of which emphasize its versatility and high clinical success–not all meet the criteria for methodological rigor and objectivity. This concern was highlighted by David Soto-Peñaloza, Regino Zaragozí-Alonso, María Peñarrocha-Diago, and colleagues in their 2017 systematic review of the "All-on-4" concept. An initial screening yielded 728 articles, of which only 24 met the inclusion criteria. Methodological quality assessment revealed that sample size calculation was performed in only one study, and follow-up periods generally included small sample sizes – a limitation that may introduce bias and lead to misleading interpretations. The reported implant survival rate beyond 24 months was 99.8%. However, current evidence remains limited due to insufficient methodological detail, lack of long-term follow-up, and small participant cohorts. Biological complications, particularly peri-implantitis, were reported in a minority of patients after an average follow-up period of two years. Therefore, the authors emphasized the need for clearer success and survival criteria, given the high prevalence of peri-implant diseases [10].

CONCLUSION

The "All-on-4" technique – which involves the placement of four dental implants (including tilted posterior implants) and the fabrication of a screw-retained, reinforced fixed prosthesis – represents an effective alternative to the placement of a greater number of implants with bone grafting procedures in cases of significant alveolar bone loss. This protocol substantially reduces treatment time, facilitates postoperative recovery, and lowers patient costs by eliminating the need for grafting materials. However, in our view, this method requires further investigation concerning the functional changes of the stomatognathic system in fully edentulous patients. Specifically, it warrants evaluation using electromyographic analysis of masticatory muscles, digital occlusion analysis, and mathematical modeling to define the critical angulation thresholds for distal implant placement.

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