Design and the future of locking-taper screwless and cementless dental implants: a narrative review

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Background and Objective: Today, endosteal implants are widely considered the state-of-the-art treatment for edentulism. A novel alternative that can negate the shortcomings and complications that accompany screw-retained dental implants, such as screw-loosening and microleakage, is the locking taper implant system. The objective of this narrative review is to explore the current design of the locking-taper screwless and cementless dental implant and the future directions it will take.

Methods: The literature was reviewed from 1969 to 2021 to identify all studies published on the locking taper implant system thus far regardless of study design through PubMed and Google Scholar. Studies in languages other than English were excluded.

Key Content and Findings: In the locking taper system, the implant and abutment are tightly fastened to each other due to elastic deformation of both components, creating a frictional seal as the implant abutment interface are fused together in a cold weld. This feature prevents the microleakage, which often leads to screw loosening, which leads to many other complications, such as peri-implantitis. The Bicon IAC™ implant's screwless locking taper mechanism has put to the test recently in several studies, which has elucidated this novel system's capabilities. Ultrashort locking taper implants (5- and 6-mm) illustrate similar survivability to short implants (<10 mm). Further, the proximity of the implant plateau to the root surface of adjacent teeth was not a risk factor for the failure of plateau root-form implants, does not alter peri-implant bone levels, does not damage to the root surface or to the crestal bone on the adjacent tooth. Dental implants are constantly evolving and have come a long way. Yet, future directions should focus post-insertion complications, multi-implant restorations such as implant-supported bridges and dentures, and different bioavailable materials for implant osseointegration.

Conclusions: The locking taper implant system is a novel design with many positive features, such as its frictional seal that eliminates the potential for microleakage and proven longevity, that counters the shortcoming of the preliminary screw-retained implant system.

Keywords: Screwless implants; cementless implants; locking taper implants

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Introduction

Dental implants were first introduced by the orthopedic surgeon, Per-Ingvar Brånemark, in 1969 when he experimented on intraosseous anchorage of dental prosthesis on dogs. The results of this experiment found that it is possible to anchor a fixed prosthesis via an intraosseous titanium fixture with a favorable clinical outcome (1). Since then, dental implants have become a staple procedure in the field of dentistry and is now widely used by oral and maxillofacial surgeons to treat single and multiple missing teeth. This subfield of dentistry has seen stark innovation since it was introduced half a century ago (2). There have been advancements in the designs of endosteal implant, from the shape of the implant to the microporosity of the implant surface (3). Thus, dental implants are the state-of-the-art treatment for missing teeth as of recent times. In the US, the use of single-tooth dental implants to treat missing teeth has increased over the last two decades (4).

Endosteal dental implants are the most common type of implant to treat missing teeth (5). This type of implant holds several clinical advantages over alternative treatments, such as partial dentures. These advantages include the preservation of bone, the preservation of tooth structure, and the resistance to caries (6). In this chapter, we will discuss the latest innovations in the field of dental implantology with a focus on the locking taper implant system. Finally, we will end by discussing the future directions that have been taken in implantology thus far. To achieve this goal, we reviewed the literature to identify all studies published on the locking taper implant system thus far regardless of study design through PubMed and Google Scholar.

Since Dr. Brånemark's breakthrough study on intraosseous dental implants, dental implantology has been innovated in countless ways. The application of dental implants is not just indicated for replacing individual missing teeth *per se*—endosteal implants can be utilized in the form of implant-retained overdentures (IRODs), implant-supported overdentures (ISODs), implant fixed complete dentures (IFCDs), and implant-supported metal ceramic (MC) reconstructions (7). The IROD is a removable denture that is retained in place by the way of endosteal implants. IRODs offer a high success rate, high patient satisfaction, adequate bone maintenance, adequate stability, and adequate retention (8). The ISOD is a fixed denture that is stabilized by endosteal implants. Patients who have been treated with ISODs report improved masticatory performance and an improved quality of life when compared to treatment with conventional dentures. The geriatric population notice significant improvement in their quality of life when they are treated with ISODs since tooth loss and bone loss is more prevalent as patients age (9,10). Computer-aided design (CAD) and computer-aided modelling (CAM) can be utilized to fabricate IRODs and ISODs. CAD/CAM technology in IROD and ISOD fabrication can reduce treatment times significantly for patients. More development is needed in CAD/CAM technology as intraoral scanners are unable to digitalize the various tissues in the oral cavity as well as the functional movements of the patient (11,12). The use of implants is especially beneficial for patients due to their aesthetics, better quality of life, and improved denture retention. Patients that have been treated with endosteal implants also report far fewer disabling symptoms than alternate treatment options, such as conventional dentures (6,7). We present this article in accordance with the Narrative Review reporting checklist (available at https://fomm.amegroups.com/article/view/10.21037/fomm-21-116/rc).

Methods

To accomplish the objective of this study, all relevant studies were searched to complete this narrative review. The search strategies are summarized in *Table 1*. To facilitate the comprehensiveness of the review, the authors did not limit this review to a particular study design. Consistent with others (13), the authors also did not deem it necessary to critique the selected articles. In addition, the references for all selected studies were screened to identify any other potential studies that could augment the review. The selection process was conducted by author D Stanbouly, AYZ Li, and R Stanbouly using the following terms: locking-taper implants; cementless implants; dental implants.

Implant fixture porosity

The high long-term success rate of osseointegrated dental implants has been well documented as its use is increasing (5). The highest contributing factor to the success rates of osseointegrated dental implants is the surface roughness of the implant fixture (14). Osseointegration is defined as "the process resulting in direct structural and functional connection between ordered, living bone and the surface of

Table 1 The search strategy summary

Items	Specification
Date of search	08/01/2021–11/01/2021
Databases and other sources searched	PubMed, Google Scholar
Search terms used	Locking-taper implants; cementless implants; screwless implants; dental implants
Timeframe	1969–2021
Inclusion and exclusion criteria	Inclusion criteria consisted of articles written in English that concerned locking-taper and cementless implants. No particular study type was preferred. Articles written in languages other than English were excluded
Selection process	The selection process was independently conducted by Dani Stanbouly, Rami Stanbouly, and Alexander Li

a (load-bearing) implant" (15). Successful osseointegration is seen when primary stability and secondary stability is achieved. Primary stability is defined as "the mechanical interlocking between the bone and the implant without biological interplay" and is considered as a critical factor in the long-term success of implants. Secondary stability is achieved when biological factors begin to form from both the host bone tissue to the implant and the implant to the host bone. Implant fixture porosity can allow improved osseointegration and rapid bone growth by increasing the implant surface area contact with bone. Porosity of the implant fixture can be achieved by using material with a rough structure or by modifying the surface of the fixture (16). The implant fixture surface roughness is most commonly tailored to enhance porosity (3). The surface roughness of an implant fixture advances osteogenesis and, ultimately, successful osseointegration of the implant (14).

Different materials of the implant fixture have been tested to achieve porosity over time. Pure titanium (cp-Ti) and the Ti6Al4V alloy are the most widely used material for implant fixtures (17). The reason that titanium and titanium alloys are widely used as implant materials is due to their ability to form a passive film that is resistant to the corrosive biologic species in the human body. The passive film is generally composed of an oxidized layer (titanium dioxide) and films formed by exposure to various solutions (18). The film of titanium dioxide can manipulate biomineralization by attracting calcium and phosphate ions to form calcium phosphate, which is a thermodynamically stable substance that mimics the crystallization present in bone (17).

Ceramic is another material used for implant fixtures. Bioactive ceramic has a similar effect to titanium, releasing calcium phosphate ions around the implant to improve osseus healing. Ceramic, as a dental biomaterial, was first introduced as abutments and coatings. Bioactive ceramic coatings on implant fixtures have shown to increase microroughness and improve osseointegration. Zirconia implants can be a practicable alternative to titanium implants because it is aesthetically superior in addition to its biocompatibility (19,20).

The latest material that has been used in dental implants are polymer-based biomaterials. Polymers are indicated for use as a dental implant material for reasons such as its biocompatibility with tissues, excellent processability, and easily tailored physical properties (19). Poly-ether-ether-ketone (PEEK) is a polymer material that is already used in orthopedics (20). PEEK is a favorable material for use in implant dentistry because it has an elastic modulus that is very similar to that of bone (21). Although PEEK is bioinert and does not conduct cell adhesion on its own, surface modifications, such as a coating of titanium, can improve its biocompatibility (22). Although PEEK is a suitable material for implants, more investigation on the safety of PEEK in dental implants is warranted.

Implant fixture length

Although the success rate of dental implants may be high, there are multiple factors, clinician- and patient-related, that can lead to implant failure (23). The main cause of implant failure is intrinsic to the patient: poor bone quality and quantity (24). Bone quality is classified into four groups corresponding to the proportion of compact and trabecular bone tissue. Group 1 is large homogenous cortical bone. Group 2 is dense trabecular bone surrounded by a thick layer of compact bone. Group 3 is dense trabecular bone surrounded by a thin cortical layer. Lastly, group 4 is a core of low-density trabecular bone surrounded by a thin cortical layer. The implants failure rates are higher for bone groups 1 and 4 relative to bone groups 2 and 3 (23,25).

Failure of the implant can be of primary or secondary nature. Primary implant failure is when the implant completely fails to osseointegrate, whereas secondary failure is when marginal bone resorption leads to clinical failure of the implant. Secondary implant failure constitutes the majority of implant failure cases and has been demonstrated to be secondary to poor clinical handling, poor implant design, or the complexity of the case, among other reasons (23). The location of the implant may be a determinant of implant failure. Implants placed in the mandible exhibit higher survival rates than implants in the maxilla, particularly the posterior maxilla (26). Another key factor that may cause the failure of an implant is the volume of bone. Bone volume in the mandible and maxilla can be compromised in various ways, such as smoking, aging, and periodontitis (27).

Dental implants have seen many different structural changes since its inception. Modifications in fixture surface roughness and length have been contributory to the high success rate of dental implants (3). One factor that has generated a need for dental implant modifications is the progressively increasing geriatric population. Aging individuals are more prone to tooth loss and periodontitis. Furthermore, the extent of periodontal destruction increases with age (28,29). The bone loss secondary to periodontitis renders longer implants a less desirable choice since there is not enough bone to contain the length of the implant. Short implants are suited for patients with reduced bone levels and those that are unable to undergo complex surgeries (30). Though there is no consensus, implants are considered ‘short’ by most authors when their length is less than 10 mm (31,32). This threshold can be as low as 4 mm according to some authors (33,34). Short implants are more easily inserted than long implants and bone grafts are often unnecessary (35). The survival rates of short implants are comparable to conventional implants on grafted or pristine bone (36,37). Marginal bone loss occurs less often in short implants (less than 6) compared to long implants (greater than 8) (35). Although the literature indicates that short implants have a higher failure rate than conventional implants, applying properties of biomechanical stress reduction, such as increasing the surface area of the implant screw via the number of threads, can increase success rates (32). Though further investigation is needed, short implants can be implemented in fixed implant-supported prosthesis in addition to single-tooth restorations (38).

Locking taper implants

One of the more common applications of dental implants is the single tooth implant restoration. Single tooth implant restorations produce highly satisfied patients and are characterized as highly esthetic by both patients and dentists (8,39). Typically, the implant systems used in single tooth implant restorations consist of the implant fixture, the abutment, which connects to the fixture, and the crown, which seats on the abutment. The abutment is commonly retained to the implant fixture using a screw (40). Although this retention method has been employed for over 35 years, it is not without complications. The implant abutment interface of screw-retained implants has been observed to be contaminated with bacteria due to microleakage (41). This microleakage occurs through the hollow spaces of the abutment screw access, which can facilitate the growth of microbial species present in the oral biofilm. This microleakage into the implant abutment interface can still occur with the use of sealing materials to cover the abutment screw access channels (42).

Abutment screw loosening is the most common mechanical complication. Screw loosening can lead to other complications, such as screw fracture, marginal gap, peri-implantitis, microbial leakage, and patient discomfort. Many factors are implicated in screw loosening. Implants with shorter screws and smaller diameters are more likely to loosen. Further, the phenomenon of microleakage discussed earlier has been shown to lead to screw loosening. Screw loosening is particularly prevalent among single tooth restorations and has been clinically reported in up to 48% of cases (43). The abutment screw can also break—the occlusal forces, which are concentrated at the screw *per se*, often far exceed the typical preload of a torqued abutment-implant system (44).

Cement can be utilized to reinforce structural integrity of the crown-abutment complex. Nevertheless, excess cement can enter the gingival sulcus. It is often challenging to remove this excess cement since the margins are subgingival, increasing the likelihood of cement being forced into the sulcus when the restoration (i.e., crown) is being seated. This can ultimately lead to peri-implant bone loss (45,46).

A novel alternative that can negate the shortcomings and complications that accompany screw-retained dental implants is by using a locking taper implant system (41). The Bicon Dental Implant™ system (Bicon, LLC, Boston, MA, USA) is an implant system that is screwless. The implant is connected to the abutment by a locking taper mechanism, tightly fastened to each other due to elastic deformation of both components. This creates a frictional seal because the two surfaces of the implant abutment interface are fused together in a cold weld, which has exhibited excellent clinical reliability (47-49).

Mangano *et al.* conducted a 10-year prospective study on the survival and complication rates of fixed restorations on locking-taper implants. The final sample consisted of 642 patients with a total of 1,494 locking taper implants that was equally distributed between the maxilla and mandible. The overall 10-year cumulative implant survival rate of was an impressive 98.7%. The survival rate did not differ significantly based on location, with the mandible (99.1%) being slightly higher than that of the maxilla (98.3%). Further, the 10-year complication free survival rate was 88.6% (43).

Latest innovations

The creation of Bicon IAC™ ultrashort locking-taper implants (5- and 6-mm) to facilitate prosthetic restoration where limited bone height is available for some patients led to the evaluation of their performance compared to Bicon IACTM demonstrated similar survival rates for short (≥8 or ≤10 mm) and regular-length implants (>10 mm) for replacing missing teeth in partially or complete edentulous patients (50,51). Furthermore, survival of 6.0-mm-wide × 5.7-mm-long Bicon IAC™ implants is comparable to that of longer conventional implants, and therefore it was hypothesized that survival of ultrashort implants would be similar to survival of short implants (52).

A study evaluating the performance of 5-mm-long implants. The sample consisted of 291 subjects who received 410 Bicon IAC™ locking-taper implants, 211 of which were ultrashort implants (57: 5 mm × 5.0 mm and 154: 5 mm × 6.0 mm) with the remaining 199 being short implants (5 mm × 8.0 mm). Urdaneta *et al.* found no significant correlation between implant length and implant failure. That is, ultrashort implants had similar survival rate compared to the short implants, supporting the hypothesis that ultrashort locking-taper implants are clinically acceptable to facilitate prosthetic restoration where bone height is limited (53).

Another innovation introduced to the Bicon IAC™ system was the concept of bone-loading platform switch, in which an implant shoulder progressively slopes inward and coronally toward the implant-abutment boundary to create space for crestal bone, while the base of the abutment offers loading surface through which compressive loads may be exerted on existing crestal bone (54). Endosseous implants are popular treatment alternative for the replacement of single teeth, and research has shown that the best predictor for long-term success of implant restorations is minimal crestal bone resorption (55,56). The purpose of this study was to evaluate the effect of overloading forces within proximity on adjacent teeth using the bone-loading platform switch and to investigate the effect of tooth proximity on implant survival and peri-implant bone levels (54). Previously, it was identified that marginal bone loss has been associated with high occlusal stress with splinted smooth-surface implants, and contrarily, crestal bone growth has been associated with increased overloading forces in long-term studies; therefore, there is no clear relationship between overloading forces and peri-implant bone levels (55,57,58).

Through a retrospective cohort study, 206 patients who had received at least one 5-mm wide hydroxyapatite-coated single-tooth Bicon IAC™ implant placed adjacent to one natural tooth (range, 0–14.6 mm) were included for total of 235 plateau root-form implants with follow-up for average of 42 months. Descriptive statistics and regression models were utilized to determine the relationship between horizontal distance between implant and adjacent tooth (variable) and change in peri-implant bone levels over time (outcome). Proximity in 43 out of 235 implants were placed <1 mm to an adjacent natural tooth on mesial and/or distal side(s), and it was determined that proximity of plateau root-form implants was not associated with post-operative complications on adjacent tooth (e.g., bone loss, root resorption, endodontic treatment, pain, extraction). Overall, this study (within limitations) demonstrated three major conclusions: (I) the distance between the first implant plateau and root surface of an adjacent tooth did not influence failure of plateau root-form implants; (II) no significant correlation between tooth-implant proximity and changes in peri-implant bone levels surrounding plateau root-form implants existed; (III) placing a plateau implant in close proximity to an adjacent tooth does not cause detectable damage to the root surface or to the crestal bone on the adjacent tooth (54).

Modifications to improve crestal bone gain in the Bicon IAC™ implant system has been advanced progressively within the past decade. Reports of various levels of bone loss ranging from 0.12–0.20 mm (after 1 year) and an additional 0.01–0.11 mm (after 2 years) have been reported after the insertion of single-tooth implant restorations, while crestal bone gain has also been recognized after 1 year of follow-up with chemically modified surface around immediate loaded locking-taper implants (58-60). Therefore, it was important to understand for patients who have received Bicon IAC™ implants, what factors are associated with crestal bone gain post-operative of single-tooth restorations.

One factor that has been proven to have statistically significant correlation with crestal bone gain is the daily intake of nonsteroidal anti-inflammatory drugs (NSAIDs). Through a retrospective cohort study, 81 subjects who had received 326 Bicon IAC™ implants were followed for average of 70.7 months, and through multivariate statistical analysis, it was determined that daily intake of NSAIDs ($P=0.02$) were correlated with significant increase in crestal bone levels around single-tooth hydroxyapatite-coated implants ($P=0.01$). Other factors that are positively correlated with crestal bone gain include having adjacent tooth/teeth as opposing structure ($P=0.02$), crown cemented on prefabricated titanium abutment with spherical base ($P=0.006$), and implant size of 5 mm × 8 mm ($P=0.02$) (61).

In the same retrospective cohort analysis, another study had investigated on the effect of increased crown heights on crestal bone stresses and complications, whether increased crown-to-implant ratio (C:IR) on single-tooth implants had any effect on crestal bone loss. With mean C:IR =1.6 (range, 0.79–4.95), implant restorations with increased C:IR were found to have significantly higher mesiodistal crown width, larger implant diameter, deeper periodontal probing depth, more loosened crowns (maxillary), and higher chance of fractures (posterior). Therefore, it was determined that higher the C:IR could lead to prosthetic complications but not significant effects on crestal bone levels for Bicon IACTM single-tooth implant restorations (62).

Lastly, this study evaluated the effect of opposing structures on crestal bone levels around single-tooth implants: 231 opposed natural teeth, 75 opposed implant-supported restorations, 10 had no opposing structure, and 4 opposed complete dentures. Statistical analysis indicated that the average change in crestal bone levels overtime (AvBL) was 0.20 and 0.62 mm for natural teeth and implant-supported restorations, respectively. In addition, the type of material coated on mandibular implants demonstrated different AvBL, with hydroxyapatite of AvBL =+0.01 and titanium-plasma sprayed (TPS) of AvBL =1.95. Therefore, this study illustrated there is a significant role in mandibular crestal bone levels based on both the type of supportive material and the opposing structures of the Bicon IAC™ implant system (62).

Future directions

The screwless and cementless single-tooth, implant-supported crowns (IAC™) technique offers some advantages compared to traditional implant dentistry, such as marginal adaptation with cementless border, completely sealed implant-abutment transition, crown material with similar wear rate and hardness values comparable to human enamel, time-efficient laboratory technique, and reduced number of prosthetic requirements. However, there are unfortunately still major drawbacks for Bicon IAC™ implant system, especially for the resin materials, including but not limited to high roughness values, high plaque accumulative rate, and high stain level (49).

Dental implants were first introduced back in the 1970s, and it is expected to grow $13 billion in revenue by 2023. As the aging population continues grow with multiple comorbid medical conditions such as osteoporosis, diabetes mellitus, and obesity, the long-term survival rate of dental implants is endangered as osseointegration and bone healing are compromised (3). Research into biocompatible materials for implant dentistry has become popular, and one example of which is Smileloc™ guided nitinol-retained single-tooth dental implant restoration. The nitinol metal alloy is superplastic, is stronger than fastening screw or cement when securing crowns, and can mold into different shapes via shape memory to allow for adaptability within the oral and maxillofacial complex and can be considered as future cementless and screwless crown material that saves time and cost (63). For implant bridges and full-arch prostheses, more novel materials, such as TRINIA™, are demonstrating more favorable outcomes than traditional materials, such as metal alloys (64). TRINIA™ is a metal-free fibre-reinforced CAD/CAM material that is comparable to dentin. The multidirectional fibreglass and resin interlacing provides this material with flexural strength that gives it dentin-like qualities. Using CAD, this material provides more cost-effective and efficient alternatives for dentists and dental laboratories (3).

Nevertheless, Bicon IAC™ implant system upholds a high survival rate overall based on previous retrospective cohort study (98.7%) with cementless interface, color stability, and reduced number of prosthetic components (40). Future directions can be taken towards studying including but not limited to post-insertion complications, multi-implant restorations such as implant-supported bridges and dentures, and different bioavailable materials for implant osseointegration.

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Footnote

Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at https://fomm.amegroups.com/article/view/10.21037/fomm-21-116/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://fomm.amegroups.com/article/view/10.21037/fomm-21-116/coif). SKC serves as an unpaid editorial board member of *Frontiers of Oral and Maxillofacial Medicine* from July 2020 to June 2024. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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