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Cost-effectiveness analysis of two attachment systems for mandibular overdenture

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Abstract

Objectives: This study analysed the cost-effectiveness of two different attachments for the 2-implant overdenture (2IOD) in edentulous mandibles.

Materials and methods: When considering alternative treatments, cost-effectiveness analysis is an important factor for stakeholders (patient, clinician, social security, insurance company, etc.). A general practice population (n = 116) was treated between 2003 and 2013 with a mandibular 2IOD with 2 different ball/stud attachment systems, one spherical (Group D) and one cylindrical (Group L). Patient well-being was assessed with OHIP-14-Total (OHIP-14-T), at intake and annually up to 5 years, to calculate the health effect. Initial and maintenance costs of both treatments were inventoried. The cost-effectiveness was compared. Annual discount rates of 4% and 1.5% were applied to future costs and health outcomes, following Dutch guidelines. Prices were adjusted to the year 2003. To offset the uncertainty in relevant input parameters, a sensitivity analysis was performed using bootstrap analysis. Significance was set at $p < .05$.

Results: The health effect was 6.36 (SD 5.32) for Group D and 8.54 (SD 5.63) for Group L. The sum of the discounted costs up to 5 years was EUR 4,210.98 (SD 634.75) for the D and EUR 3,840.62 (SD 302.63) for the Group L (p = .005). The bootstrapping reports that L abutment clearly dominates the D abutment in terms of cost-effectiveness.

Conclusions: The 2IOD on the L abutment is dominant compared to the 2IOD on D abutment, in a 5-year perspective.

KEYWORDS
ball abutment, cost-effectiveness, denture maintenance, locator abutment, mandibular overdenture

1 | INTRODUCTION

Mandibular implant overdentures are generally accepted as a long-term stable and good solution for the edentulous patient in the mandible (Feine et al., 2002; Thomason et al., 2009). Unfortunately, implementation of this treatment is often jeopardized by the initial treatment cost and possibly also the maintenance cost. Estimates of health outcomes and costs are important for healthcare planning and of interest to healthcare providers, third-party payers and, last but not least, patients (Takanashi, Penrod, Lund, & Feine, 2004). There is a growing interest in dental research to

perform economic analysis of a specific dental treatment, even though in the low- and middle-income regions it remains scarce (Hettiarachchi et al., 2018). Eurostat data show that unmet medical and dental care needs for financial reasons have increased following the economic crisis of 2008–2009 and 2011. This phenomenon is widely shared across European Union countries and is particularly strong among households in the bottom part of the income distribution. As a consequence, in choosing between alternative treatments, cost-effectiveness of dental treatment is an important factor for patients, the government (healthcare budget) and/or insurance companies. This also applies to prosthetic solutions for edentulism.

From a patients' perspective, a distinction can be made between direct and indirect cost. The former relates to all initial treatment costs including all materials and fees, as well as to the subsequent maintenance cost. Indirect costs for the patients are travel cost as well as the opportunity cost (the time spent for the medical treatment including travel time). Cost-effectiveness analysis (CEA) is the most common methodology of economic evaluation in health care and compares the relative costs and outcomes (effects) of different treatment options. The aim of a CEA is to inform decision-makers, healthcare providers and patients about the financial cost and the expected effect of medical or dental treatments. Decision-makers need this information to maximize benefits from constrained resources (Beikler & Flemmig, 2015; Listl, Tu, & Faggion, 2010). In systems with low insurance allowances or low third-party payer input, the healthcare provider and the patient need the information to make justified choices for a treatment option. In this respect, Emami et al. (2019) found that 80% of a study population recommended the conversion of the 2IOD into a 3IOD to others, but only 47% was willing to pay for that conversion.

In terms of a CEA concerning a new treatment, four cases can be distinguished. Two are unambiguous: when an intervention costs less and is more effective, the intervention is dominant. An intervention that costs more and is less effective is dominated. On the other hand, when it costs more and is more effective or when it costs less and is less effective, the choice is more difficult and dependent on whether cost or effectiveness prevails.

Cost utility analysis (CUA) is a special form of CEA, which measures the health outcome in terms of health-related quality of life (HRQoL). The preferred measure used in medicine is the Quality-Adjusted Life Years (QALY), an expression of health gain both in quality and length of life. In dentistry, the Quality-Adjusted Tooth Years (QATY), Quality-Adjusted Prosthesis Years (QAPY) and Quality of Tooth Years (QLTY) were developed as more specific outcomes to compare the cost-effectiveness of different dental treatments (Balevi & Shepperd, 2007; Bhuridej et al., 2007; Chun, Har, Lim, & Lim, 2016; Zitzmann, Krast, Weiger, Kühl, & Sendi, 2013; Zitzmann, Marinello, & Sendi, 2006). An issue with these outcomes is that they cannot be compared with results in other areas of health care (Hettiarachchi et al., 2018). To address this issue, more economically orientated methods are promoted: TTO (Time Trade-Off) or the standard gamble method (Sendi et al., 2018).

In dentistry, an index of the oral health-related quality of life (OHRQoL), the oral health impact factor (OHIP), can be used (Hettiarachchi et al., 2018; Heydecke et al., 2005) to express the oral health effect of an intervention. The oral health-specific measures applied in dentistry such as OHIP and OHIP-EDENT are not able to measure the health utility. Consequently, the outcome is expressed in OHIP points and the research is labelled as CEA.

The cost-effectiveness analysis in prosthetic dentistry allows the comparison of the cost-effectiveness across different interventions and provides useful input for the dentist in giving objective and correct information to patients in relation to treatment alternatives.

An implant overdenture is connected to the implants by an attachment system. In the mandibular 2IOD, different options are used: the bar system with splinted implants, the ball/stud, magnet or telescopic systems with un-splinted implants (Payne et al., 2018). The bar and ball/stud categories are frequently used for the 2IOD in the mandible.

Alfadda and Attard (2017) assessed over a 14-year period, the incremental cost-effectiveness ratios of an immediately loaded protocol for mandibular overdentures on an ovoid bar and clip system. They concluded that the treatment with an IOD was more cost-effective compared with conventional denture (CD) after 1 and 5 years of observation. However, the accrued maintenance and complication costs over the total 14-year period resulted in a less cost-effective treatment. Other studies compared conventional complete dentures and mandibular overdentures on 2 or 4 implants over an assumed time horizon of 10 years and concluded that implant treatment becomes cost-effective with the 2IOD if the patient is willing to pay at least CHF 3800 for a quality-adjusted prosthesis year gain based on perceived chewing ability (Zitzmann et al., 2006). Comparing CDs and 2IODs, an improvement of one OHIP-20 point costed an additional CAD 14.41 per year in an estimated 17.9 years of evaluation (Heydecke et al., 2005). Comparing 2IOD on ball and bar clip constructions, no statistically significant difference was found after 8 years of follow-up (Stoker, Wismeijer, & Waas, 2007). By and large, more clinical studies are required to further analyse the cost-effectiveness of different protocols with implant overdentures (Zhang et al., 2017) in order to assess whether one connection system is more, equally or less effective and at what cost.

Therefore, the aim of this study was to conduct a cost-effectiveness analysis comparing 2 different well-known attachment systems for mandibular 2IOD over a follow-up period of 5 years.

2 | MATERIAL AND METHODS

2.1 | Study population, surgical and prosthetic treatment

This 5-year follow-up study was performed in a dental clinic in Enschede, the Netherlands. All edentulous participants in need of an implant-retained mandibular prosthesis were consecutively treated between 2003 and 2013 with a conventional maxillary

denture and a 2IOD. The details concerning participants' selection, surgical and prosthetic treatment and the implant and prosthetic outcome are published in an earlier article (Matthys et al., 2019). In brief, each participant received two implants (Astra Tech Osseospeed, Dentsply Sirona implants) of diameter 3.5 or 4.0 mm and length 7–13 mm. Implants were placed under local anaesthesia, with a one-stage surgical protocol, in the anterior mandible. Healing abutments were placed immediately after implant insertion, and the existing denture was adjusted with a resilient liner (Ufigel SC, Voco). After a conventional healing period (i.e. 4 months), new maxillary and mandibular dentures were fabricated with the corresponding patrices and matrices: the spherical Dalbo with Classic or Plus matrix (Cendres + Métaux-Medtech) or the short cylindrical Locator Legacy abutment (Locator, ZEST

Anchors LLC) (Figure 1a–e). The 2 cohorts were treated according to the system used in the clinic at the moment of implant placement. Initially, Dalbo abutments (Group D) and, from 2007 on, the Locator Legacy (Group L) became the exclusive abutment of choice. Hence, the study is not based on randomized groups but on consecutively treated cohorts. The implant placement and the fabrication of the prostheses were done by the same dentist (J.B.), and a regular professional maintenance protocol was installed. Throughout annual clinical research examinations, an independent team of calibrated prosthodontists and periodontists of the Department of Periodontology and Prosthodontics of the Ghent University Belgium collected the research data. The study was approved by the ethical committee of the Ghent University Hospital (EC UZ 2005/414), and all participants gave written consent.
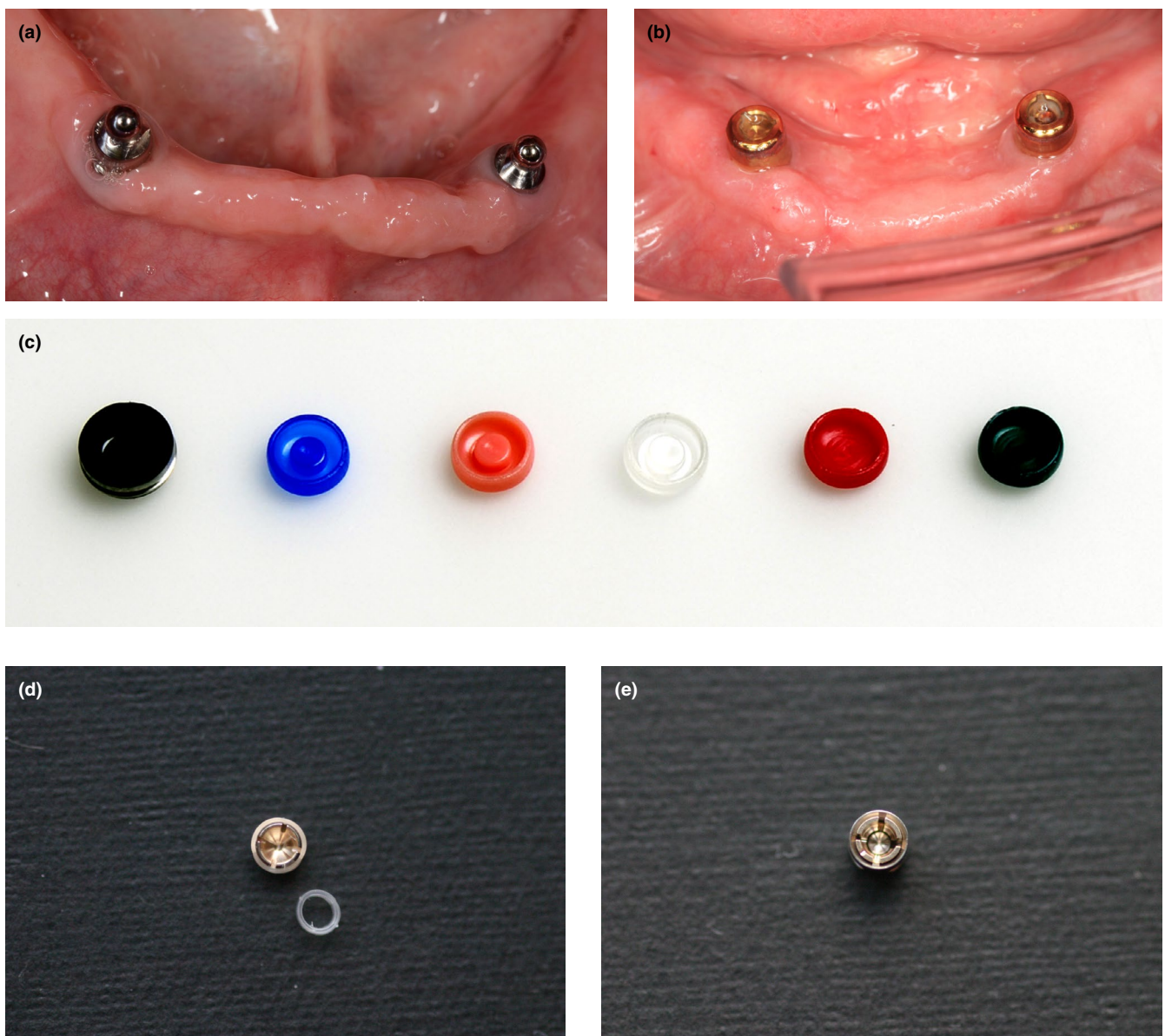

FIGURE 1 (a) Clinical view Dalbo attachment. (b) Clinical view Locator Legacy attachment. (c) Locator Legacy metal housing for placement in denture. Black laboratory insert, blue, pink and transparent denture inserts and red and green extended range inserts. (d) Dalbo Classic matrix for placement in denture. (e) Dalbo Plus matrix for placement in denture

2.2 | Measurement of the health effect with OHRQoL outcome measure

At intake and during the annual research follow-up sessions, the OHRQoL was measured based on the OHIP-14-T, a validated self-reporting questionnaire based on 14 items in 7 dimensions: functional limitation, pain, psychological discomfort, physical disability, psychological disability, social disability and handicap (Slade, 1997). All items were scored on a Likert scale ranging from 0 (very positive) to 4 (very negative), and the sum of all items corresponds to the OHIP-14-T, ranging from 0 (very positive) to 56 (very negative).

The health effect (HE) was calculated based on the OHIP-14-T. A reduction in the OHIP-14-*T* score reflects an improvement in the oral health well-being of the participant. In calculating the HE, one needs to consider the number of days that the participant cannot use his denture due to maintenance. In addition, the timing of the OHIP-14-T improvement is also important because participants will prefer a quick improvement to a delayed one. To take this into account, a discount rate of 1.5% was used, in line with the standard for health outcome measures applied in the Netherlands (Attema, Brouwer, & Claxton, 2018).

The following sum was calculated with the yearly registered OHIP-14-T values.

[(OHIP 1-year Follow-up (FU) − OHIP intake)/2] × [(365 − x1)/365]/[1 + 0.015] + [(OHIP 2-year FU − OHIP 1-year FU)/2] × [(365 − x2)/365]/$[1 + 0.015]^2$ + [(OHIP 3-year FU − OHIP 2-year FU)/2] × [(365 − x3)/365]/$[1 + 0.015]^3$ + [(OHIP 4-year FU − OHIP 3-year FU)/2] × [(365 − x4)/365]]/$[1 + 0.015]^4$ + [(OHIP 5-year FU − OHIP 4-year FU)/2] × [(365 − x5)/365]/$[1 + 0.015]^5$.

The OHIP-14-T change registered on the occasion of the annual consultations versus the previous result is divided by 2 because we assume that OHIP-14-T evolves linearly over time. In that case, a patient with an OHIP-14-T of X at the start of an observation period of 12 months and an OHIP-14-T of Y at the end of that period will have had an average OHIP-14-T throughout the year of X + (Y − X)/2. The notations x1, x2, x3, x4 and x5 represent the number of days that the dentures could not be used during the specific years due to maintenance interventions. Table 1 provides a detailed list of the maintenance inventory, the average number of days the denture could not been used and maintenance specifications for groups D and L.

2.3 | Calculation of the initial and maintenance cost

The study analysed the cost from a client perspective, regardless of who paid for the costs (patient or healthcare insurance). The baseline initial cost was registered and included: presurgical planning, implant surgery including material cost and dentist fee, prosthetic cost including all materials, dentist and technician fees. The technical maintenance cost per year was recorded (including all materials and fees). This included repair of maxillary and mandibular dentures, all interventions and replacements of the attachment systems, new implants if needed, new dentures, consultations for ulcers or pain and small interventions such as professional cleaning of the dentures in the laboratory and retightening of ball/stud abutments. Due to the difference between the 2 abutments used, the activation of retention for the Dalbo Classic and Plus was done with the appropriate tools, and for Locator L, the inserts were changed (Table 1). The cost for the annual preventive recall was not taken into account as recall is not specific for this population and this prosthetic rehabilitation.

The indirect costs were not taken into consideration, because indirect costs will be very participant dependent. The population in this study lives in the neighbourhood of the dental centre, and most of the participants are retired. More generally, the socio-economic characteristics of the participants population could end up biasing the overall results should indirect costs be included in the assessment. No indirect clinician's costs were applied either because the focus of the study was on the participant's perspective, rather than analysing the profit for the dentist.

In order to allow for a more detailed analysis, the average number of maintenance interventions per participant was calculated as well as the interventions with high cost and/or missing denture days for the participant. Analysing costs over a considerable period of time raises two issues. Firstly, healthcare costs need to be discounted, because a participant will prefer paying later rather than sooner. To this end, a discount rate of 4.0% was used, in line with the standard applied in the Netherlands (Attema et al., 2018). A sensitivity analysis was conducted to assess the influence of different discount rates. Using the same discount rate for costs and outcomes (1.5%) yielded negligible differences, so only the results applying the official guidelines will be reported. Secondly, inflation introduces a bias when comparing initial as well as technical maintenance costs over time between participants. The participants analysed in this article have received their 2IOD between 2003 and 2013, and hence, the initial cost was converted into prices of the same base year (2003 was used). This conversion was done by dividing the 2IOD cost in a given month by the Dutch overall consumer price index excluding energy, food, alcohol and tobacco (Eurostat). For technical maintenance costs, the inflation adjustment was conducted after applying the 4% discount rate mentioned above.

2.4 | Cost-effectiveness of both treatment modalities

The cost-effectiveness analysis was conducted by comparing incremental costs (Locator Legacy versus Dalbo) with the incremental health effect. In addition, incremental net health benefit and incremental net monetary benefit for varying willingness to pay were calculated. Finally, cost-effectiveness acceptability and affordability for each treatment option were analysed.

TABLE 1 Details of maintenance inventory

Type of maintenance intervention	Group D specification	Group L Specification	Intervention days
Repair (maxillary denture/mandibular overdenture)			2
Rebasing (maxillary denture/mandibular overdenture			3
Retention correction per implant	Adjustment of retention with appropriate instrument	Change of insert	1
Ulcer correction or pain problem			0
New maxillary denture and mandibular overdenture (with old in function)			0
New Abutment without rebasing			0
New Abutment with rebasing/repair			See repair or rebasing
New matrix without repair/rebasing	Matrix Classic or Plus	Metal insert housing and insert	2
New matrix with repair/rebasing	Matrix Classic or Plus	Metal insert housing and insert	See repair or rebasing
New Implant with denture in function			0
Loose abutment tightening			0
New mandibular overdenture (with old functional)			0
New maxillary conventional denture (with old functional)			0
Cleaning denture in dental technician laboratory			1
Change to other retention system (per implant) without new denture	1 Ball to Locator	1 Locator to Ball	3
Change to other retention system (per implant) with new denture (old denture functional)	1 Ball to Locator	1 Locator to Ball	0

Note: Specifications for groups D and L. Average number of days denture not functional during maintenance.

2.5 | Statistics

The normality of the data was tested with the Kolmogorov–Smirnov test, which showed that the data were skewed. However, for a sufficiently large number of observations, which is the case in this study, the mean is normally distributed. Hence, a *t* test was used to compare the results for the two attachments. The level of significance was set at $p < .05$. The calculations were done with SPSS software 25 (SPSS Inc.).

Given the uncertainty about the true mean values of input parameters, sensitivity analysis was performed using a bootstrapping
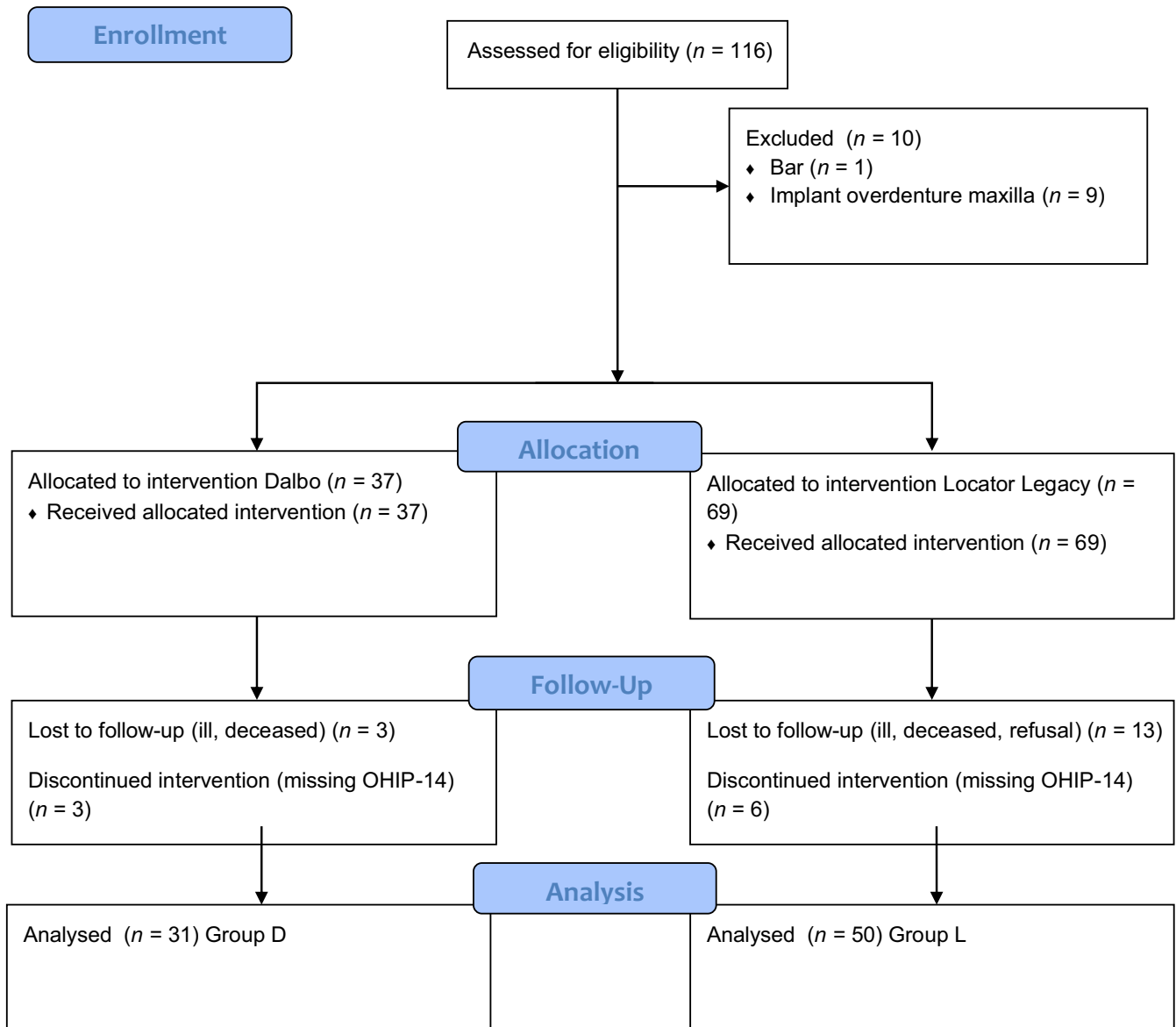
Assessed for eligibility (*n* = 116)

Excluded (*n* = 10)
♦ Bar (*n* = 1)
♦ Implant overdenture maxilla (*n* = 9)

Allocation

Allocated to intervention Dalbo (*n* = 37)
♦ Received allocated intervention (*n* = 37)

Allocated to intervention Locator Legacy (*n* = 69)
♦ Received allocated intervention (*n* = 69)

Follow-Up

Lost to follow-up (ill, deceased) (*n* = 3)

Discontinued intervention (missing OHIP-14) (*n* = 3)

Lost to follow-up (ill, deceased, refusal) (*n* = 13)

Discontinued intervention (missing OHIP-14) (*n* = 6)

Analysis

Analysed (*n* = 31) Group D

Analysed (*n* = 50) Group L

FIGURE 2 CONSORT flow diagram

analysis (10,000 simulations). For each simulation, constituents of the original samples were randomly selected, whereby each constituent was represented by the effect and the associated costs so as to take into account the dependency between effects and costs. The simulations were conducted in Matlab (version R2018b academic use).

3 | RESULTS

3.1 | Study population

In total, 116 edentulous participants were consecutively treated, receiving 232 implants. One participant received, on his request, a bar overdenture and was therefore excluded. In the 5-year evaluation period, 9 participants received an implant overdenture in the maxilla, which also led to exclusion as this could possibly bias the outcome in terms of effect and cost. This implies that in total 106 participants entered the 5-year follow-up study. Over time, 16 participants dropped out: 8 died, 6 were too old or too ill to attend the recall sessions at the clinic, one participant declined further follow-up and in one participant missing values at baseline required exclusion. Ninety participants (55 men and 35 women) with a mean age 65.8 (range 41–83), at time of surgery, were included in the 5-year data registration. The Group D consisted of 34 participants, who received Dalbo abutments. Group L consisted of 56 participants receiving Locator Legacy abutments. For the calculation of the health effect (HE) in OHIP-14 points, another 9 participants (6 Locator L, 3 Dalbo) could not be included due to missing OHIP-14-T values for one or more intermediate years. Consequently, 81 participants (31 in Group D and 50 in Group L) were included as presented in Figure 2: Consort Flow Diagram.

TABLE 2 Oral HE in terms of improvement in OHIP points in mean values and *SD* for both groups L and D; 1- to 5-year and a 2- to 5-year perspective. Discount rate 1.5% (Dutch standards)

	Group L (*n* = 51)	Group D (*n* = 30)	Significance (*p*)
HE 0–1 year	8.68 *SD* 5.51	6.46 *SD* 5.57	.078
HE 2–5 years	0.15 *SD* 1.75	0.06 *SD* 1.88	.839
HE 0–5 years	8.34 *SD* 5.65	6.36 *SD* 5.32	.089

Abbreviations: HE, Health effect in OHIP-14 improvement; *SD*, standard deviation.

3.2 | Health effect outcome in OHIP points

The discounted oral health effect on a 5-year basis, expressed in change in OHIP-14 points, was for Group D −6.36 [standard deviation (*SD*) 5.32] and for Group L −8.34 (*SD* 5.65) (*p* = .089). Multiplying this expression with −1, one obtains the improvement in OHIP-14 points. This multiplication allows for an intuitively clear interpretation of quality improvement, which is a mathematically positive number, and was necessary because improved health well-being corresponds to a decline of the OHIP-14-T score.

The health effect was also calculated for the periods 0–1 and 2–5 years. As shown in Table 2, the positive effect is mainly concentrated in the first year (pre- to post-treatment effect) and not in the later years. This is explained by the fact that the OHIP-14-T improvement is mainly observed after placement of the implant overdenture and not in later years of the follow-up process.

3.3 | Cost calculation and technical maintenance inventory

The initial cost for Group D was EUR 3,817.43 (*SD* 258.45, range [3052.22–4264.25]) and for Group L EUR 3,585.78 (*SD* 221.32, range [3049.10–4011.12]) (*p* < .000).

The maintenance cost based on all technical interventions was for groups D and L, respectively, EUR 393.55 (*SD* 585.9, range [0–2454.52]) and EUR 254.84 (*SD* 230.70, range [0–961.87]). They were not statistically significantly different. The sum of all costs up to 5 years was EUR 4,210.98 (*SD* 634.75, range [3,252.40–6,327,23]) for Group D and EUR 3,840.62 (*SD* 302.63, range [3,215.59–4,564.67]) for Group L (*p* = .004). Table 3 gives an overview of the values. Although not the primary aim of the study, the average number of

technical prosthetic interventions per participant is shown in Table 4. The Locator Legacy 2IOD has an important number of low-cost interventions, mainly caused by the change of the retention inlays and the consultations for ulcer problems. The maintenance interventions for the Dalbo overdenture are predominantly due to interventions with a higher cost and "missing days denture" profile.

3.4 | Cost-effectiveness

In order to assess the cost-effectiveness of both overdenture alternatives (2IOD Dalbo and 2IOD Locator Legacy), incremental costs (Locator Legacy versus Dalbo) are compared with the incremental health effect based on a bootstrapping analysis. In conducting the simulations, the dependency between costs and effects was taking into account. The outcome is represented in a cost-effectiveness plane in Figure 3 (Fenwick, Claxton, & Sculpher, 2001; van Hout, Al, Gordon, & Rutten, 1994). Incremental costs are almost exclusively negative, which means that the Locator Legacy solution is cheaper than the Dalbo. Moreover, the incremental health effect is overwhelmingly positive, implying that the effect is larger for Locator Legacy than for Dalbo. As a consequence, in the vast majority of cases, Locator Legacy is a dominant solution (lower costs, higher health effect).

3.5 | Sensitivity analysis

A sensitivity analysis was conducting by calculating the incremental net benefit for varying willingness to pay. "Incremental" refers to the difference in net benefit of one attachment versus the other. The net health benefit (NHB) is equal to the effect (E) minus costs (C) divided by the willingness to pay (λ): NHB = $E - C/\lambda$. The net monetary benefit (NMB) corresponds to NMB = $\lambda E - C$. As discussed in Stinnett and Mullahy (1998), the willingness to pay (λ) represents the amount a patient or society, in the context of the public health budget, are willing to pay for a given gain in health. A high willingness to pay thus reflects that the patient is very eager to have a given treatment and is less sensitive to the cost aspect. This approach is very useful when considering alternative solutions. Comparing Locator Legacy and Dalbo, the incremental net monetary benefit can be calculated: INMB = λ(effect L − effect D) − (cost L − cost D). As shown in the incremental net monetary

TABLE 3 Overview of cost values in prices of 2003 (EUR) for Group D and L in mean values, standard deviation (*SD*), range (R)

	Group L (*n* = 51)	Group D (*n* = 30)	Significance
Initial cost	3,585.78 *SD* 221.32 R 3,049.10–4,011.12	3,817.43 *SD* 258.45 R 3,052.22–4,264.25	*p* < .001
Discounted maintenance cost 5 years	254.84 *SD* 230.70 R 0–961.87	393.55 *SD* 585.89 R 0–2,454.52	*p* = .907
Initial + discounted maintenance cost	3,840.62 *SD* 302.63 R 3,215.59–4,564.67	4,210.98 *SD* 634.75 R 3,252.40–6,327.23	*p* = .005

Discount rate 4% (Dutch standard).

TABLE 4 Overview average number of interventions per patient 5-year follow-up

	Group L (n = 51)	Group B (n = 30)
All interventions	6.68 SD 4.77	3.06 SD 2.17
Interventions high cost and/or days missing denture	2.14 SD 2.29	2.74 SD 2.24

Note: Groups L and D. Mean values and *SD*.
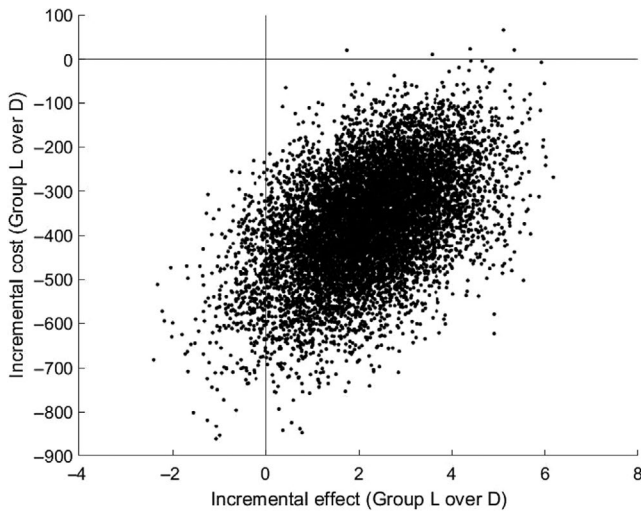
Abbreviation: *SD*, standard deviation.

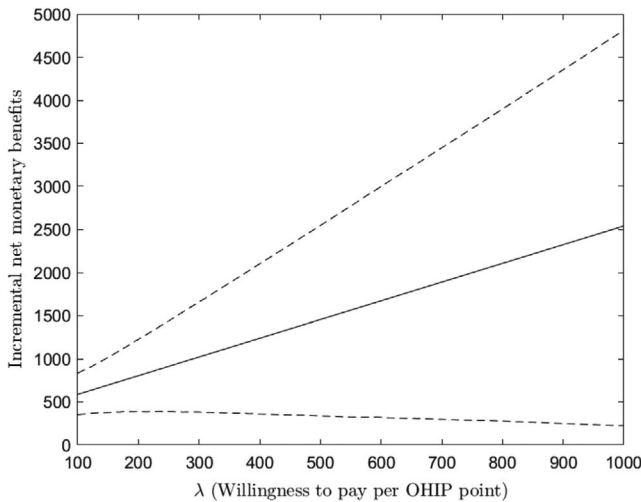**FIGURE 3** Cost-effectiveness plane: incremental effect and incremental cost

FIGURE 4 Incremental net monetary benefit (Group L versus Group D) with confidence interval

benefit curve in Figure 4, L dominates D and increasingly so when the willingness to pay increases.

The cost-effectiveness acceptability curve (Figure 5) shows, for varying willingness to pay, the probability of a positive incremental net health benefit. Even for high levels of willingness to pay, the
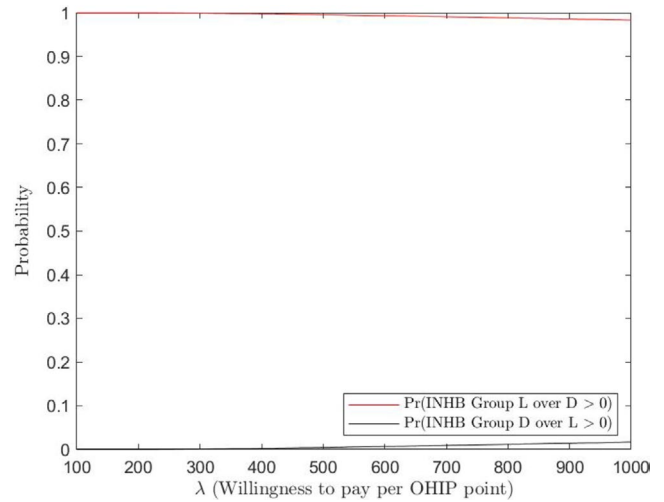

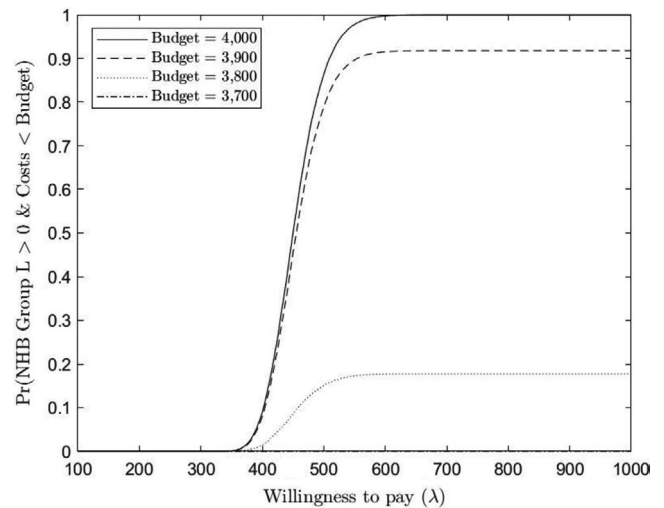**FIGURE 5** Cost-effectiveness acceptability curve

FIGURE 6 Cost-effectiveness affordability curve (Group L)

probability that L (D) has positive incremental net health benefit compared to D (L) is very high (low).

Although the net health benefit may be positive, the question remains whether the intervention is affordable. This is addressed by the cost-effectiveness affordability curve (Figure 6), which shows, for varying willingness to pay, the probability of a positive net health benefit under the condition that costs respect the budget constraint (Sendi & Briggs, 2001). For Locator, this probability is very high. For Dalbo on the contrary, it is very low.

4 | DISCUSSION

In this study, an analysis was made of the cost and the oral health effect outcome of two attachment systems, the Locator Legacy and the Dalbo (Classic of Plus) for 2IOD after 5 years. Previous research on cost and effect of 2IOD (ball and bar) constructions reports a gain in oral outcome

effect in comparison with conventional dentures, provided the patient is willing to pay a certain price. Comparison between studies is often difficult for various reasons, the most important being the implementation of indirect participants cost, the extrapolation of cost or effects in future years and variations in dentist fees among countries (Alfadda & Attard, 2017; Heydecke et al., 2005; Zitzmann et al., 2006). The study of Alfadda on 2IOD comparing two loading protocols on bar/clip attachment and inclusion of the indirect participants cost reports an overall cost of CAD 255.60 per point OHIP-20 improvement at the denture insertion and CAD 170.58, CAD 210.38 and CAD 478.70 at the 1-, 5- and 14-year follow-ups, respectively. The research of Zitzmann et al. (2006) compared conventional dentures and 2 types of implant overdentures (2 and 4 implants). In a 3-year analysis, the cost per quality-adjusted prosthesis year gained with implant overdentures is CHF 9100 for the 2 implants overdenture on Ball abutments and CHF 19800 for the 4 implants bar overdenture. The 10-year extrapolation reports values of CHF 3800 for the 2 implants ball and CHF 7100 for the 4 implant bar overdenture. In the work of Heydecke et al. (2005), conventional dentures and 2 IOD on ball attachments were analysed. The 1-year results comparing cost (direct and indirect) and health effect in OHIP-20 points were the basis for an extrapolation up to 17 years, reporting a supplementary cost for 2IOD treatment of CAD 14.41 per OHIP-20 point per year. Studies analysing the cost-effectiveness of a Locator Legacy 2IOD on a 5-year perspective are to our knowledge not available.

In the present study, the oral health effect in the 5-year perspective was not statistically significantly different, as could be expected, as both 2IOD options (Dalbo and Locator L) have a positive effect on the oral health-related quality of life (Matthys et al., 2019). Therefore, this aspect will not be the most important one when discussing treatment planning and selection with a patient.

On the other hand, the initial cost, the maintenance costs and the total cost are important points to be analysed. The initial as well as the total costs are statistically significantly different between the two alternatives, and thus, the patient (or third payer) can expect to have lower costs with a Locator Legacy 2IOD. The difference between the two alternatives is EUR 370. Such a difference is not without importance for a third-party payer, taking into account the number of 2IOD that need to be paid for or at least financially supported, per year. The factor maintenance cost is of particular importance when discussing the choice for an attachment system with the individual patient, but it is also more complex. In both systems, maintenance cost is inevitable, but the much range for the Group D suggests that the uncertainty about future maintenance costs is higher for Dalbo than for Locator L. The Locator Legacy overdenture on the other hand will need more, but less complex maintenance interventions. The more frequent change of the retention inserts and the higher incidence of ulcer and pain consultations explain this difference (Matthys et al., 2019). Yet, despite an additional cost per OHIP-14 point improvement of EUR 170 for a Dalbo 2IOD, this system could be envisaged for certain patients if we take the number of maintenance interventions into consideration: minimizing the likelihood of frequent interventions could be important for patients with limited mobility or for patients with time constraints. On the other hand, for patients with more limited financial resources, the possibility

of more high cost interventions with a Dalbo 2IOD can be a prohibitive factor. This was not analysed in this study: such an assessment is highly subjective and hence patient-dependent. Indeed, some patients might be willing to pay more and prefer the less cost-effective ball 2IOD, if this would possibly imply fewer visits to the dentist.

Discussing cost-effectiveness, the conclusion is unambiguous: although in terms of health effect, the results for Group L are not statistically significantly different from the results for Group D. The difference as far as costs are concerned is statistically significant, with Locator Legacy costing less than the Dalbo 2IOD in this 5-year follow-up study. Going forward, a longer-term evaluation is needed to assess whether this superior cost-effectiveness of the Locator Legacy 2IOD can be maintained or if the system, as stated in other research on 2IOD with bar, will end up being less effective over the years (Alfadda & Attard, 2017).

Some limitations must be noted. The result in this study reports on two attachment systems for overdentures: the Dalbo (Classic and Plus) and the Locator Legacy. The results and cannot be extrapolated to the other attachment systems including the new generation of the Locator R-TX. The allocation to Group D or Group L abutment group was done on a time-based decision and not randomized per se. However, the participants were sequentially treated by the same dentist in the same region: in a first period, Dalbo was exclusively used, whereas in a second period Locator Legacy attachments were exclusively placed. This implies that participants' inclusion in a certain group only depended on the abutment type, which was exclusively used in that period. This should limit the possible bias from the non-randomization of the allocation. Another consequence is a different number of cases for both attachments, covering different time periods. For this reason, time-discounting and inflation adjustment have been applied. Not including the indirect participant cost could be seen as a limitation. However, taking indirect costs into account would raise many other issues. Initial and maintenance costs are objective data, whereas including indirect costs would require putting an economic value on them. This is a very subjective, participant-dependent matter, which also depends on the sociological profile of the participant population.

5 | CONCLUSION

Based on the available 5-year follow-up data, and in a European context, the 2IOD on Locator Legacy is more cost-effective than the 2IOD on Dalbo (Classic or Plus) system. This outcome is essentially the result of the initial cost difference of both systems.

Statement: On behalf of Ghent University, Prof De Bruyn declares a research collaboration agreement with Dentsply Sirona.

AUTHORS CONTRIBUTIONS

Carine Matthys involved in the data collection and wrote the article. **William De Vijlder** involved in the economic analysis and statistics, revision of article and approval of article. **Jos Besseler** involved in the prosthodontics and implant placement and approval of article. **Maarten Glibert** involved in the data collection and approval of article. **Hugo De Bruyn** designed the study and involved in the data collection, revision of the article and approval of article.

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SUPPORTING INFORMATION

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